PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY,

HELD AT PHILADELPHIA, FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XXIV. JULY TO DECEMBER, 1887. No. 126.

TABLE OF CONTENTS.

	PAGE.
A Contribution to the History of the Vertebrata of the Trias of North America. By *E. D. Cope (with two plates)*	200
Were the Toltecs an Historic Nationality? By *Daniel G. Brinton.*	229
Biela's Comet and the Large Meteors of November 27–30. By *Daniel Kirkwood*	242
Notices of New Fresh-water Infusoria. By *Alfred C. Stokes (with a plate)*	244
Preliminary Report on the Vertebrate Fossils of the Uinta Formation, collected by the Princeton Expedition of 1886. By *W. B. Scott and Henry F. Osborn (with a cut)*	255
On the Systematic Position of the Mallophaga. By *A. S. Packard (with thirteen cuts)*	264
On the Reptiles and Batrachians of Grand Cayman. By *Samuel Garman*	278
On West Indian Reptiles in the Museum of Comparative Zoölogy, at Cambridge, Mass. By *Samuel Garman*	278
Memoir of Pliny Earle Chase. By *Philip C. Garrett*	287
Octonary Numeration and its Application to a System of Weights and Measures. By *Alfred B. Taylor*	296
On the so-called Alagüilac Language of Guatemala. By *D. G. Brinton*	306
The Classification and Phylogeny of the Artiodactyla. By *E. D Cope*	377
Biographical Notice of Isaac Lea, LL.D. By *Joseph Leidy*	400
Stated Meeting, September 2, 1887	403
Stated Meeting, September 16, 1887	410
Stated Meeting, October 7, 1887	412
Stated Meeting, October 21, 1887	414
Stated Meeting, November 4, 1887	416
Stated Meeting, November 18, 1887	417
Notes on the Ethnology of British Columbia. By *F. Boas*	422
Electrolysis of Lead Solutions. Determination of Boric Acid. Dihalogen Derivatives of Salicylic Acid. Barite. By *Edgar F. Smith*	428
Stated Meeting, December 2, 1887	434
Note on the Possible Existence of Fireballs and Meteorites in the Stream of Bielids. By *Daniel Kirkwood*	436
On an Ancient Human Footprint from Nicaragua. By *D. G. Brinton (with a plate)*	437
Stated Meeting, December 16, 1887	444

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2. Persons of any nation, sect or denomination whatever, shall be admitted as candidates for this premium.

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A Contribution to the History of the Vertebrata of the Trias of North America. By E. D. Cope.

(*Read before the American Philosophical Society, April 15, 1887.*)

The vertebrata of the Trias of North America are not as yet well known, and scarcely twenty species have been described. Those known to the writer in 1870 are enumerated in the Transactions of this Society, Vol. xiv; and the species discovered in Pennsylvania are catalogued in the Proceedings of this Society for 1886, p. 403. Some species from New Mexico are described in the American Naturalist, 1881, p. 922,* and April, 1887. Descriptions of several forms from this formation, from the Rocky Mountain region, with plates, were given in the Report of the U. S. Geol. Geogr. Survey W. of the 100th Meridian, 1877.

I am now able to add descriptions of some new species from New Mexico; and furnish additional characters of species already described.

1. EUPELOR DURUS Cope. Transac. Amer. Philos. Soc., 1869, p. 25, V. xiv.

A good many fragments of this species or one nearly allied to it were obtained by Mr. C. M. Wheatley, in York county, Pennsylvania. These pieces are not all as yet identifiable, but one of them consists of a large part of the ramus of the lower jaw which supports the bases of the posterior teeth, but from which the cotyles and angles have been broken off. The bases of the teeth are cylindric, and show delicate grooves, being similar to those of Eryops, and proving that my original reference of teeth to this genus was probably correct. All the bones show the coarse honeycomb pattern of sculpture of the external surfaces characteristic of the species. Towards the margins of the bones the pits become confluent into radiating grooves. A subtriangular plate measures:

	M.
Length	.345
Greatest width	.140

* *Belodon buceros* and *B. scolopax* Cope.

PROC. AMER. PHILOS. SOC. XXIV. 126. 2A. PRINTED JULY 8, 1887.

The fragment of jaw measures: M.

Depth at last tooth ..... .040
Length, including three teeth ..... .027

Nothing can yet be determined as to the characters of the vertebræ of this form.

2. TYPOTHORAX COCCINARUM Cope. U. S. G. G. Survey W. of 100th Meridian, Capt. G. M. Wheeler, 1877, iv, Pt. ii, p. 30. Pl. xxii, figs. 4, 5 and 9. American Naturalist, 1887, p. 468.

The genus Typothorax was distinguished by me, l. c., from Belodon, on account of the regularly pitted surface of the dermal bones. With such dermal bones others of a different character were found, which it was thought best to refer to the same genus, and a fragment of maxillary bone found near by was included in the description. I now suspect that the dermal bones which do not possess the pitted character belong to some other reptile, and the fragment of jaw is not to be referred, certainly, to the *Typothorax coccinarum*, but is more likely a part of a Belodont Saurian.

The additional material belonging to this genus and species which I possess consists of two ribs with corresponding dermal bones attached to their superior surfaces, and two femora, one of which adheres to one of the ribs. Also several other more or less incomplete dermal bones. There are numerous other bones accompanying, but their reference is not certain.

Char. Gen. The peculiarities of this genus as displayed by these specimens are as follows: Ribs greatly expanded but with free margins, each overlaid by a band-like dermal bone for its entire length. The dermal bones with pitted sculpture and straight, simple margins, the one acute and the other obtuse. The margins of the ribs are similar to each other. It results that a gaping groove is formed between the parallel acute edge of the dermal plate and the rib into which the appressed edges of the adjacent rib and plate enter and fit. Thus is formed a complete cuirass covering the body. Femur sigmoid, without distinct head or trochanters, excepting a prominent, ridge-like third trochanter on the posterior face. Condyles with a posterior lobe separated from the external lobe by a fossa.

It is possible that one of the ribs described is abdominal in position, as it does not appear to have had a head. There is no head preserved on the other. The dermal bands described may be therefore abdominal. The ribs are, however, strongly curved in the longitudinal direction, and it is to be supposed on this account that they are dorsal, and perhaps in the position of flying ribs. The adhesion of a femur to one of them indicates posterior position. The character of the femur is different from that of the Belodontidæ in its trilobate condyles, approaching thus the Goniopod Dinosauria. The third trochanter is much better developed than in any known Belodont.*

* Von Meyer Palæontographica, vii, 1861.

Future comparison must be had with the genus Aëtosaurus Fraas,* which accompanies Belodon in the Upper Keuper of Wurtemberg. That genus is encased in parallelogrammic scuta arranged in contiguous cross-bands, on both surfaces of the body. But the scuta are not co-extensive with the ribs as in Typothorax; at least the latter are represented by Fraas as much narrower than the osseous dermal bands. The latter are also transversely subdivided in Aëtosaurus.

It is highly probable, however, that Typothorax represent Aëtosaurus in the Upper Trias of North America, and may belong to the same family of the order Rhynchocephalia.

The relations of the dermal bones and ribs are highly interesting. The great expansion of the latter needs but the development of sutural surfaces on their borders to produce an osseous continuum. The same modification of the dermal bones above it would form a second external roof. A subsequent fusion of the superior and inferior roofs would give us the testudinate carapace. And this history would be what embryology teaches us is the origin of that remarkable modification of the dermal and true skeleton exhibited by that order of reptiles. It is probable that Typothorax is nearly allied to the type from which the order of tortoises has been derived. It is unfortunate that we know nothing of its skull and vertebræ, but there is nothing in the characters of the femora to preclude the above hypothesis. They belong to a type which progressed in a prone position, and which probably differed much from both Belodonts and other Dinosauria.

Char. Specif. Ribs strongly convex in the longitudinal direction; in the transverse direction flat above, and with a longitudinal convexity below. This convexity occupies about one-third of the inferior surface, and extends obliquely to one of the lateral borders at the extremity. At the other extremity the surface is flat, the rib-convexity disappearing. In both ribs one edge is subacute and the other obtuse. The rib-thickening runs out to the thin edge. The dermal scuta have the same width as the ribs. They have thicker and thinner edges corresponding with those of the ribs. Where the rib-thickening of the latter is prominent, the dermal bone has a median convexity below; and this disappears at the other end as the thickening does from the rib. The superior face of the dermal bones is perfectly flat. It is sculptured with coarse shallow pits, separated by obtuse ridges, which have a reticulate pattern, since the pits are not in rows.

These osseous bands are probably in contact, thus forming an impenetrable buckler, as in Aëtosaurus. One edge of the osseous combination of rib and dermal plate gapes, the thin edges of the two elements diverging so as to receive the margin of the adjacent band. The matrix along this border is clearly impressed so as to prove the former presence of the succeeding portion of the carapace.

* *Aëtosaurus ferratus* Fraas; Festschrift zur Feier d. vierhundertjährigen Jubiläums Univ. Tübingen, 1877.

Measurements.	M.
Length of rib on curve on inner side	.276
" " chord of rib	.250
Width of rib near proximal end	.090
" " " distal end	.074
Thickness of rib at proximal end	.005
" " " middle	.014
" " scuta at proximal end	.005
" " " " middle	.011
" " " " distal end	.008
Average diameter of fossæ of do.	.007

The *femur* is quite characteristic. The long axes of the extremities form an angle of about 45° to each other. The shaft is incurved from the third trochanter proximad, and is expanded more externally than internally at the distal extremity. The proximal extremity is rhomboid in outline; the internal border convex, the anterior concave, the posterior less concave, and the postero-exterior nearly straight, and joining the anterior by an acumination with obtuse apex, which represents the great trochanter. Surface of head, flat-convex. The junction of the internal and external posterior faces is marked by a convexity; and the shaft below the external posterior face is longitudinally concave. The third trochanter marks about two-fifths the length of the shaft, and is quite prominent. It is convex externally, and concave internally. Below it the section of the shaft is a transverse oval, wider exteriorly. The condyles of the femur are considerably expanded transversely, the external being the most produced. The rotular groove is shallow but distinct. The external condyle, as already remarked, has a distinct posterior lobe, which is separated from it externally by a large ? ligamentous fossa within the bonndary of the articular surface. This posterior lobe is well within the exterior border, and bounds the intercondylar groove on the external side. It presents posteriorly, and is narrowed and obtuse. A corresponding part of the internal condyle presents posteriorly also.

Measurements of femur.			M.
Total length (axial)			.230
Diameters of head	anteroposterior (greatest)		.060
	transverse (axial)		.035
Anteroposterior diameter at great trochanter			.031
Diameters of shaft	anteroposterior		.022
	transverse		.030
Diameters of condyles	transverse		.081
	anteroposterior	internally	.040
		at groove	.032
		at posterior lobe	.051

The parts of this individual preserved indicate an animal of the average

size of the Mississippi alligator. More perfect specimens will be awaited with much interest.

3. EPISCOPOSAURUS HORRIDUS. Gen. et sp. nov.

This species is indicated by a number of bones which were excavated at the same place. They are: Two caudal vertebræ, a proximal and a distal; a humerus; two ulnæ; a femur lacking the condyles; a proximal part of a tibia; the distal part of a fibula; a calcaneum, and a number of dermal bones. The only part of the skull possibly belonging to this animal is a splenial bone.

Char. Gen. The generic characters, so far as ascertainable from the materials, resemble those of Belodon with certain exceptions. Chief among the latter is the disproportion, in dimensions, between the anterior and posterior extremities, which is as great as that existing in many Dinosauria proper. Appropriately to this relation, the femur differs from that of Belodon in the absence of curvature of the shaft, having the straight form of that of most Dinosauria proper. There are no trochanters of any kind on this femur, and its head has the wedge-shaped Belodon outline. The head and condyles of the humerus are transversely expanded; the shaft is contracted; condyles not specialized. No epicondylar foramina of either side, but a strong ectepicondylar groove, which cuts off a narrow ectepicondylar ridge, which terminates freely. The caudal vertebræ are elongate, indicating a powerful tail. But one species is yet known.

Char. Specif. The body of the anterior caudal vertebra has a wedge-shaped section, the apex inferior, representing the section of an obtuse median keel. The articular faces are subcircular, widening upwards. Both are concave, the posterior more so than the anterior, which is nearly plane. No lateral ridges on the body. Arch lost. The posterior caudal is long and slender, and has a long compressed neural arch. The section of the body is heptagonal, as there are two low lateral angles on each side, and an obtuse median inferior keel. The inferior lateral angle is stronger than the superior. There is not so much difference in the concavity of the articular extremities, as in the case of the larger vertebra.

Dimensions of caudal vertebræ.		M.
Length of centrum of anterior vertebra		.070
Diameters of anterior face	transverse	.050
	vertical	.048
Length of centrum posterior vertebra		.069
Diameters anterior face	transverse	.033
	vertical	.031

The *humerus* is remarkable for the small diameter of its shaft as compared with the expanse of its extremities. The long axes of these extremities make an angle of about 45° with each other. The articular surface, which is co-extensive with the head, is long and narrow, widening

gradually to the inner rounded extremity. Viewed in profile it is strongly convex, the convexity being a little nearer the internal than the external extremity. The articular surface descends on the inner edge of the bone towards but not to the bicipital crest. Viewed proximally, the convexity of the head is as wide as the inner extremity, and is distinguished from it by a concavity of the inner side. The bicipital crest is the incurved external border. It commences opposite the prominence of the inner extremity of the head, and extends but a short distance down the shaft. It is quite prominent. The face of the bone below the head displays a very shallow concavity. The posterior face is recurved towards the two margins, as we approach them. The shaft is very much contracted. Its section at the middle is a wide oval; the external edge subacute, the internal broadly rounded. The distal extremity is much expanded, though not so widely as the proximal end. The expansion is greater internally than externally. Neither epicondylar prominence, however, extends much beyond the articular surface. The latter is rather narrow, and is curved, the concavity anterior. The two extremities are wider than the middle region, the external part being the widest. There is a deep groove on the posterior face near the external edge, which runs out, leaving the external epicondylar process to terminate at about 20 mm. proximad of the condyle. The latter terminates outwards in an acute angle, which marks the internal edge of the ectepicondylar groove. The epitroclear fossa is well defined. Posterior face plane.

Measurements of humerus.				M.
Total length				.220
Diameters of head	long (straight line)			.088
	transverse	internal		.025
		greatest (submedian)		.024
		least (external)		.015
Diameters at middle of shaft	anteroposterior			.021
	transverse			.027
Diameters of distal end	transverse	with ectepicondylar crest		.076
		below " "		.072
	anteroposterior	internal		.021
		median		.018
		external		.029

The *ulna* is characterized by its small size, and its great compression, especially of the distal half. The olecranon is deep, but it scarcely projects behind the cotylus, where it is more prominent than at the inferior border. On the external side a regular convex mark extends from the base of the coronoid process to the inferior posterior angle. Behind this arc-like border, the surface of the bone is dense and smooth, as though for a cartilaginous cap. What this structure indicates it is difficult to understand, as it is clearly not a muscular insertion. The coronoid process is quite prominent. The external face of the shaft is convex in the

vertical section; the internal flat. The vertical diameter increases a little at the distal extremity. The latter is in the plane of the shaft, and is gently convex in both directions. Its narrow proportions indicate a correspondingly feeble carpus.

Measurements of ulna.		M.
Total length		.161
Depth of ulna	at olecranon	.037
	at coronoid process	.055
	at middle of shaft	.026
	at distal extremity	.035
Width of ulna	at cotylus	.022
	at middle of shaft	.010
	at distal extremity	.012

Parts of the *radius* resemble considerably that of a mammal. The head as a transverse oval, slightly concave, and the shaft is quite narrow, and with an oval section.

Measurements of radius.		M.
Diameters of head	transverse	.035
	vertical	.020
Diameters of shaft	transverse	.015
	vertical	.012

The *femur* is the characteristic bone of the genus. The specimen preserved lacks only the condyles. The remainder of the bone is perfectly straight. The inner face of the shaft is rounded, becoming flat as it approaches the head. The external edge is an angle which vanishes above the middle of the shaft, to reappear again as a narrow ridge which terminates in the external extremity of the head, which is homologous with the great trochanter. A well-developed obtuse ridge, above the middle of the shaft on the posterior face, represents the third trochanter. The head occupies the entire proximal extremity. Viewed proximally, it is pyriform, with a concavity of the anterior, and a convexity of the posterior outline. The external extremity is narrowed; the internal is broadly rounded. A wide groove occupies the center of the entire articular surface. Below the middle the shaft is uniformly convex in front; while posteriorly there is a shallow groove just within the external edge.

Measurements of femur.		M.
Length of fragment preserved		.315
Diameters of head	internal	.057
	median	.052
	exterior	.030
Diameters of shaft below 3d trochanter	anteroposterior	.041
	transverse	.052

The *tibia* is represented by the proximal end only. It is much like that

of Belodon, but, like the humerus, is characterized by a relatively small diameter of the shaft. The outline of the head is wide-reniform, the shallow concavity posterior. The articular surface descends on each side of this concavity, giving a convex outline to the superficial layer of the posterior face of the bone. Anteriorly the articular region projects further to one side than to the other, perhaps leaning to the external side.

Measurements of the tibia.		M.
Diameters of head of tibia	anteroposterior (middle)...	.073
	transverse.....	.107
Diameters of shaft	anteroposterior	.032
	transverse	.043

The distal end of the *fibula* is robust. One face of the shaft is concave; the opposite one is convex. On the concave side, one-half the bone projects distad abruptly beyond the other half. On the convex side, the edge of the articular extremity winds obliquely from the one level to the other. This indicates the fact that the articular face forms a segment, equaling three-fifths, of a spiral.

		M.
Diameters distal end of fibula	transverse (axial).....	.080
	anteroposterior	.048

The *calcaneum* has the form usual in crocodiles, and especially in Belodontidæ. It is wider and flatter than in any species known to me. The external rim extends from the anterior to the posterior extremities, and is quite expanded. The distal extremity is pyriform, and its recurved edges bound posteriorly a deep fossa on both the superior and the inferior aspects of the bone. These fossæ are continuous by the open concavity of the internal margin. This margin is flared inwards in front by its truncate anterior face, which bounds the astragaline fossa behind. The latter is wider than deep. The articular surface is divided into two planes; a narrow interior for the tibia, and a wider exterior for the fibula. Both are convex anteroposteriorly, and nearly plane transversely.

Measurements of calcaneum.		M.
Anteroposterior diameters	longest.....	.90
	at astragaline fossa.....	.52
Transverse diameters	anteriorly.....	.50
	median (greatest)	.91
	posterior.....	.74

The *dermal bones* are of three types, of each of which I select an example. They are all, or nearly all, furnished with a prominence of the superior surface, which is more or less compressed, and which is abrupt at one face, and produced into a keel at the other extremity in the direction of the axis of the bone. All the bones preserved are unilateral in type. The simplest form is oval-parallelogrammic, with a low obtuse median keel, which rises at one extremity into a moderately compressed knob,

which terminates abruptly. Shallow grooves separated by ridges radiate from this prominence in all directions. On its sides the sculpture becomes smaller and more irregular. In the second type of bone, the median keel is elevated into a crest which extends the entire length, and cannot be distinguished at any point as a knob. The section of such a bone is triradiate, and it is not always practicable to state which of the three laminæ is the free one. In any case the latter is not median on the fixed portion.

In the third type of dermal bone, the free keel is much developed and rises into a tuberosity so produced as to be a well-developed spine. The inferior surface of the bone is longitudinally concave. The section of the spine is triangular, the apex being the sharp edge which is the continuation of the keel. The sharpness of this edge is such as to render it probable that these spines constituted dangerous weapons of defense. One side of the spine is nearly vertically over the edge of the base, while the other is within the other edge. The surface of the bone is perfectly smooth. None of the dermal scuta of Belodon described by Von Meyer are developed into spines like those of this species.

Measurements of dermal bones.

		M.
	No. 1.	
Diameters	anteroposterior	.100
	transverse	.070
Elevation of knob		.031
Distances of knob	from one end	.060
	from the other end	.020
	No. 2.	
Length		.085
Elevation of laminæ	No. 1.	.037
	No. 2.	.016
	No. 3.	
Diameters of base	anteroposterior	.096
	transverse	.034
Elevation of spine	from lateral border	.085
	from inferior groove (oblique)	.053
Diameters of spine at base	anteroposterior	.040
	transverse	.020

4. Belodon buceros Cope. American Naturalist, 1881, p. 922.

Some years ago* I identified certain fossils discovered in North Carolina by Emmons as Belodons; and later,† referred a species found by Wheatley in Pennsylvania to the same genus. I was subsequently able to prove that the genus ranged over the Rocky mountains, and that there, as in other parts of the world, it haunted the shores of the Triassic seas and lakes. There are two species of Belodon in my New Mexican collections,

* Proceedings of Academy of Natural Sciences, Philadelphia, 1866.
† Transactions Amer. Philos. Soc., xiv, 1869.

one as large as the gavial of India, the other smaller. In the former the muzzle is keeled above, and rises into a crest in front of the nares. In the other species the muzzle is subcylindric, and does not rise anterior to the septum of the nostrils. The larger species I call *Belodon buceros;* the smaller one *B. scolopax*, and define them below. Bones of the skeleton and of the dermal systems of this genus are common in the New Mexican beds, but I am yet unable to refer them positively to the species represented by the skulls.

Char. Specif. Size of the gavial. Muzzle slender, compressed, with a narrow median superior ridge, rising at the middle of the length into a compressed crest, whose summit is in the plane of the frontal region. Nostrils a little further anterior to the orbits than the diameter of the latter, longer than wide, and separated by a thin septum. Orbits round, looking a little upwards, the interorbital region a little narrower than each orbit. Preorbital region compressed; preorbital foramen large, inferior. The quadrate bones are directed forwards, and then downwards, and their articular faces are in the transverse line of the two rather narrow notches of the posterior outline of the parietal bone. The auricular meatus is bounded posteriorly by a descending hook-like process; and the squamosal bone is continued still further posteriorly into a short triangular acute horn. The superior surface of this bone, with the parietal and frontal, are roughened with tubercles. The palate has a strong ridge on each side, so as to be grooved. The posterior teeth have compressed denticulate crowns. Tip of muzzle lost. Total length preserved, M. .700; length of muzzle to posterior edge of nares, .420; do. from latter to lines of anterior edge of orbits, .060; do. from do. to posterior parietal notch, .160. Width at posterior border of quadrate condyles, .260; interorbital do., .048; do. at slender part of muzzle, .045. Depth of slender part of muzzle, .050; do. of elevated part, .120; do. at parietal region, .140.

This species is of the size of the *B. kapfi* Meyer, and is, in the form of the muzzle, intermediate between that species and the *B. plieningeri.*

Foramina. The alisphenoid bones embrace the olfactory lobes of the brain as far forwards as the middle of the orbits, when they contract to a foramen of moderate size. The under face of the median line of the frontal bones is openly grooved in continuation. The basioccipital has a horizontal axis, and is about as long as wide, including the condyle. Its anterior border has a median apex or projection on the sphenoid. The latter forms a transverse band of small anteroposterior diameter to a sharp transverse truncation or anterior border. Whether this is the boundary of this element or not is uncertain. It is probably merely a transverse crest, since in front of it the basicranial axis is continued. The latter is deeply concave in the middle, but sends downwards a process on each side, which fits into a notch of the posterior internal border of the pterygoids. Between these notches the pterygoids underroof the axis, and unite on the median line. This union has a less anteroposterior extent than is represented by

Von Meyer in the *B. kapfi*,* and the posterior nostrils, which commence in front of this union, have a much greater anteroposterior extent than in that species.

There is a fossa in the posterior part of the orbit which extends downwards and forwards. In the superior part of its fundus is the mouth of a canal which extends from the pineal fossa of the brain-case. I call this the *orbito-pineal* canal. It will be again referred to in the description of the brain. Below the anterior part of this fossa, and at the base of the closed interorbital part of the brain-case, is the large optic foramen. It looks outwards and forwards, and it is not certain that it is separated from that of the other side by a septum. The lateral walls of the brain-case are imperforate. There is no foramen for the trigeminus in the usual position. A portion of the superior face of the sphenoid bone is split away, and it may be supposed that the trigeminal foramen was at the base of the brain on the line where the lost portion joined the lateral walls. It must have been of small size. A canal traverses the basioccipital bone on each side, commencing in conjunction with that of the opposite side, and extending outwards and backwards, and issuing on the suture joining the basi- and exoccipital bones.

Brain. The cast of the brain-case presents several peculiarities of importance. The size is a little greater than that of an *Alligator mississippiensis* whose skull slightly exceeds that of the *Belodon buceros*. Thus the dimensions of the former are, length 500 mm., width at quadrates 290 mm.; of the *B. buceros*, length 700 mm., width 240 mm. The distribution of parts is different. The prosencephalon is relatively and absolutely smaller in the Belodon, and the mesencephalon is larger. The epencephalon is not very different in the two, and the contraction on each side of it is apparent in the one as in the other. Posterior to it, the medulla is contracted to a still smaller diameter in a manner not seen in the alligator. This region is longer in the Belodon than in the latter. The brain proper is thus bunched up or shorter and more elevated in the Belodon than in the alligator. The contraction to the rhinencephalon is more abrupt in the Belodon. What gives the Belodon its especial character is the presence of an enormous epiphysis. This body is subquadrate in form, and occupies a large fossa in the cranial roof, which is, however, not perforate. On each side of the anterior portion a process extends outwards and forwards, occupying a corresponding anteroposterior fossa in the cranial walls. The process is continued, horn-like, on each side, and the cast forms a continuum through the orbitopineal canal to the orbit. Whether this represents a nervous or arterial canal can only be surmised, but from the size of the process of the epiphysis which enters it, I suspect that a nerve formed part of its contents. There is no median distinction between the halves of the prosencephalon and mesencephalon in the brain-case, thus resembling other crocodiles. The mesencephalic bodies were probably lateral, judging from the greater width of the cast below at the middle, as com-

* Palæontographica, Vol. viii.

pared with the contraction of the part behind the epiphysis. The hypophysis is distinct but not large, and occupies a fossa of the base of the cranial cavity, very much shorter than that possessed by the *Alligator mississippiensis*. The optic nerves issue immediately above and anterior to it.

Comparison with the brain of Diadectes. In these Proceedings for 1885, p. 234, I have described a cast of the brain-chamber of a species of the Diadectidæ from the Permian bed of Texas. As a successor of the Diadectes, and as descendent of probably one of the Clepsydropidæ, considerable interest attaches to a comparison of the brain of Belodon with it.

The first point which arrests the attention in making the comparison, is the similarly huge size of the epiphysis in the two types. A foramen on each side of the base of the epiphysis in the Diadectes gave exit to a process similar to that which enters the orbitopineal canal in the Belodon, and which I called the lateral process of the epiphysis in the latter. (Plate, figs. 1–3, l f). The processes are probably homologous in the two genera, but in the Diadectes they did not extend to the orbit, unless they were continued in membranous walls. There is little resemblance between the two brains in other respects, but they agree in the small size of the prosencephalon, and in the complete enclosure of the rhinencephalon by osseous walls. In the Diadectes there is no optic foramen, but a huge trigeminus; in Belodon, an optic foramen, and a very small trigeminus.

The presence of such a huge epiphysis in the Belodon as compared with its very small size in modern crocodiles, is a point of much interest, and points to its inheritance from the reptiles of the Permian. But if, as is probable, it contained the pineal eye, the latter could not receive light directly from above, since the pariëtal foramen is wanting. The presence of a communication with the orbit becomes interesting in this connection. A minute foramen passes from the base of the rhinencephalon into the orbit in the alligator, but the homology with the *canalis orbitopinealis* is by no means made out. The *nervus orbitopinealis* may have supplied the lack of light due to the closure of the pariëtal foramen, but in what way we are left to conjecture.

The equality of size of the brain of the Belodon to that of the existing alligator is a point of interest.

There is some reason to suspect that the Diadectes relied exclusively on the pineal eye for the sense of sight. The species of the family were probably subterranean in their habits, since their humeri indicate great fossorial power, resembling those of the existing monotremes, and even the mole. The vertebræ are locked together with the hyposphen beside the usual articulations, and the arches of the neural canal form an uninterrupted roof from the skull to the tail, of extraordinary thickness and strength. That the species were not aquatic is rendered probable by the fact that the orbits do not look upwards. Their superior borders are, on the contrary, prominent and straight. Add to this fact the apparent

absence of optic foramina, and the probability that the Diadectidæ were blind and subterranean in their habits becomes great.

5. BELODON SCOLOPAX Cope. American Naturalist, 1881, p. 923.

This species is represented by a snout, which includes the anterior border of the nares; it is broken into five pieces, which should be connected with intermediate fragments, which are lost. This muzzle is a little shorter than that of *B. plieningeri*, but is a good deal more slender, the distal part having only half the diameter of the latter. Besides this character, it differs from that of *B. plieningeri* in three others. The extremity of the muzzle is not so much decurved. All the alveolæ have a more lateral exposure, and the lateral ridges of the palate are thus more distinctly seen from the side. The two teeth on the extremity of the muzzle are closely crowded together, and their large alveolæ are scarcely distinct.

The surface of the muzzle is distantly and weakly grooved and punctate. The anterior alveolæ are round, the posterior ones oval. Diameters an inch anterior to nares: transverse, .0230; vertical, .0235. Diameters three inches from extremity: transverse, .019; vertical, .0145.

6. TANYSTROPHÆUS LONGICOLLIS Cope. *Cœlurus longicollis* Cope. American Naturalist, April, 1887 (pub. May 4th), p. 368.

Numerous fragments of this genus are in my collection from the Triassic beds of New Mexico. The vertebræ resemble in various essential characters those which are preserved and described by Marsh as belonging to the species of his genus Cœlurus, and I therefore referred the present species to that genus, as above cited. It is now clear to me that the Triassic species must be distinguished from Cœlurus. Prof. Marsh states that the anterior cervical vertebræ of the latter have the anterior articular surfaces convex, while the posterior are concave. In the Triassic species the third cervical is concave at both extremities, thus resembling the posterior centra. In searching for a name for the Triassic genus, I find that the Tanystrophæus of Von Meyer will probably include the American species in question. This genus was established on caudal vertebræ which nearly resemble those of the New Mexican species. For the present then I will retain for them the generic name first given to the *Tanystrophæus conspicuus* of the Trias of Würtemberg.

The bones in my possession are from all parts of the skeleton, excepting jaws and teeth; fragments of skull, if present, are not yet determinable. These show that Tanystrophæus with Cœlurus,* must be referred to a family of the carnivorous suborder (Goniopoda) of the order Dinosauria. The acetabulum is widely perforate, its pubic and ischiadic processes being widely separated from each other. The pubis has a slender shaft directed downwards, as in Compsognathus, and in Creosaurus† as figured by Marsh, with an anteroposterior expansion proximally, but no symphysis distally. On the other hand the ischia have a symphysis. The

* Amer. Journal Sci. Arts, p. 339, Plate x.

† Amer. Journal Sci. Arts, 1884, Pl. xi, l. c., p. 340.

claws are compressed and strongly curved, and capable of very extensive flexion and extension. I cannot therefore agree with Prof. Marsh that Cœlurus cannot be referred to any known order.‡ It is in fact allied to Megadactylus (Hitchcock) from the Trias of Massachusetts, differing principally, so far as determinable, in the form of the condyles of the femur. They are simple in Cœlurus, but in Megadactylus, the external condyle has the double character seen in Megalosaurus.*

The vertebræ are all of slender proportions, especially those of the neck and tail. These, with most of the bones of the limbs, are hollow, having large central cavities surrounded by thin walls, as in Megadactylus. The parapophyses are confined to the anterior parts of the centrum. In the cervical and dorsal vertebræ there is a conical fossa at each base of the neurapophysis, which unite by their apices in the cervicals, forming a canal distinct from that for the vertebral artery. The zygapophyses are partly interlocking, having convexo-concave oblique articular surfaces. There are four vertebræ of the sacrum (in *T. bauri*), whose arches are coössified as well as the centra. The anterior caudal vertebræ only have chevron bones. Prof. Marsh says they are wanting in the genus Cœlurus; but he does not appear to have possessed the most anterior of the series. In neither species is there a distinct third trochanter of the femur; but there is not far below the great trochanter on the anterior face, a low longitudinal, ridge-like angle. The femoral condyles have but little antero-posterior extent, which implies but little flexure of the knee.

The form seems to have been that of a terrestrial reptile which walked readily on the hind legs, and was probably a great leaper. The extremely long neck is a striking peculiarity, having proportions to the body about like that of the swan. The habits were probably predaceous and carnivorous.

Three species are indicated by my collections.

Char. Specif. Cervical vertebræ one-third longer than those of *Cœlurus fragilis* Marsh, the sides of the centrum not sulcate, the anterior articular face of an anterior centrum not convex. The faces are oblique, showing that the head was carried above the level of the body.

		M.
Length of body of ? third cervical vertebra		.063
Diameters of posterior cup	vertical	.016
	transverse	.019

The *dorsal centrum* has subround articular faces, which are gently concave, and a much contracted shaft. The section of the latter is subround, a little flattened below. The inferior border of the neural arch is coössified and extends well down on the side, its inferior border being marked by an open longitudinal groove. On the superior border of the middle of this groove is an indistinct tuberosity. Above this line at the middle of the neural arch a thin longitudinal broken ridge probably repre-

* See Cope, Trans. Amer. Philosoph. Soc., xiv, 1870. Pl. xiii.

sents the base of the diapophysis. It is bifurcate for more than one-third of its length at each end, the bounding walls embracing a deep conical fossa. The walls of the centrum are thin, including a large central cavity.

		M.
Length of centrum of dorsal vertebra		.042
Diameters of posterior face	vertical	.020
	transverse	.021
Elevation of centrum to middle of diapophysis		.022
Transverse diameter of neural canal		.006

A caudal centrum is much elongate and has somewhat oblique articular surfaces, though they are not so strongly so as in the case of the cervical vertebra. The arch is lost from the specimen, so that nothing can be said of the diapophyses. The articular surfaces are distinctly concave, and the anterior is a little wider than deep, while the posterior is as wide as deep. The middle of the centrum is depressed, giving a well-defined inferior lateral longitudinal angle. There is also a low median inferior angle, which gives way posterior to the two ridges that terminate in the chevron facets, which are separated by a groove.

		M.
Length of caudal centrum		.051
Diameters posterior face	vertical	.023
	transverse	.021

Another caudal vertebra is much smaller, and has no chevron facets. It is more depressed than the larger one above described, and it has a wing-like lateral angle which connects the superior parts of the articular surfaces. Inferior surface flat, bounded on each side by a low angle. Neural arch distinct. It is a question whether this vertebra belongs to this species. It appears to me to be one of the terminal caudals.

		M.
Length of centrum		.035
Diameters of posterior extremity	transverse	.0105
	vertical	.0075

The *ilium* consists almost exclusively of a frame for the large acetabulum, and supports for the pubis and ischium. The anterior and posterior extensions are insignificant. The anterior process is somewhat depressed; the posterior is compressed. The external border of the acetabulum is produced, forming a roof, which is continued nearly to the articulation of the pubic process, and which ceases at a greater distance above the articulation with the ischium. The inner acetabular border is produced downwards, partially closing the acetabulum at its fundus. The pubic articular surface is rather larger than the ischiadic, and has a gently sigmoid longitudinal section, the middle being concave. The pubic surface is on the contrary gently convex in all directions, its outline being triangular. The apex of the triangle is continued into the posterior border of the acetabulum. The sacral or internal side of the ilium is flat.

Measurements of ilium.	M.	
	No. 1.	No. 2.
Anteroposterior extent at articulations below...	.065	.086
Depth at pubis	.036	
" " ischium	.042	
Anteroposterior diameter acetabulum	.035	.049
Width above acetabulum	.021	.034

The ilium No. 2 may belong to a species distinct from No. 1, as it possesses an anteroposterior crest continued upward from the interior or sacral face, and the external roof of the acetabulum is sloped downwards exteriorly. The question of distortion prevents me from deciding the meaning of these differences at present.

The *pubis* is a very elongate bone, with a proximal extremity widely dilated anteroposteriorly. The proximal end is fan-shaped, the expansion from the axis being posterior. The proximal extremity is narrow, but is widest anteriorly, and displays three surfaces. The anterior one is for the ilium, the middle one is part of the acetabular border, and the posterior and narrowest is for the ischium. The foramen for the internal femoral artery is below the acetabular portion. The anterior border of the pubis to the extremity is rib-like, while the posterior is laminiform. The internal lamina is continued from the antero-internal face, and forms a concavity with the postero-external. Its exact width is not determinable for a good part of the length, for owing to its tenuity its edge is broken off. The distal extremity does not appear to have been united to that of the other side; if it was it could only have been by the laminar edge. The extremity is something like the head of a crocodile's humerus, the laminar edge terminating in the usual position of a deltoid crest. The shaft of the pubis is nearly straight.

Measurements of pubis.		M.
Length of shaft (a small part wanting)		.228
Diameters proximally	anteroposterior	.057
	transverse (widest)	.020
Diameters distally	anteroposterior	.023
	transverse	.012

The *ischium* is less perfectly preserved, the head and the distal parts only remaining. The ischia form a long symphysis distally, but are not suturally united or coössified. The distal end is moderately expanded anteroposteriorly, and resembles in section a half ellipse. The proximal end has the iliac face a little concave, and the acetabular surface oblique to it, and more concave. The pubic contact is broken off.

Measurements of ischium.		M.
Diameters proximally	anteroposterior	?
	transverse	.024
Diameters distally	anteroposterior	.030
	transverse	.014

The confluent extremities of the ischium form a surface of contact with the earth on which the animal probably rested at times, as I have suspected to be the case with the genus Megadactylus.* The pubes are directed downwards, and being longer than the femora have projected below the knees. It is probable that the animal rested on the apices of these bones also, as suspected by Marsh in the case of the Goniopoda of the Jurassic.

The *femur* is remarkable for the incurvature of the proximal extremity, so that it might be said to have a neck, but that there is no great trochanter. This form is necessary to avoid contact with the large pubic region. The shaft is a slightly flattened cylinder at the middle, and is a little flatter below. Rotular groove slight. Internal condyle narrower than external, and produced a little farther posteriorly.

		M.
Length of femur		.215
Diameters of condyles	anteroposterior	.024
	transverse	.030
Diameters of shaft at middle	anteroposterior	.014
	transverse	.016

Neither bones of the lower leg nor of the tarsus are certainly preserved. A phalange is of considerable size, and indicates perhaps the first of the internal digit, which is especially large in Megadactylus. The trochlear surfaces are well marked and smooth, the proximal simple, the distal hour-glass-shaped, and with well-marked lateral ligamentous fossæ. The two ligamentous insertions of the proximal extremity are well developed and of unequal size.

		M.
Total length		.043
Diameters, proximal	vertical	.018
	transverse	.015
Diameters, distal	proximal	.013
	transverse	.013

An *ungual phalange* is remarkable for its abrupt but regular curvature, and its great compression. The superior edge is the arc of a circle whose center is on the inferior edge just in front of the ligamentous insertions. The latter form a ridge of each side, just in front of the articular face, and are separated by a deep fossa. The insertion of the extensor ligament is a concave triangular space above the articular surface. The apex is lost.

Vertical depth of unguis	.018
Width do. at base of articular face	.010

This unguis is so proportioned as to have fit the penultimate phalange

* Transac. Amer. Philos. Soc., 1869, Plate xiii.

of the digit to which belonged the phalange previously described above. It indicates powerful prehensile use of the feet.

The *Tanystrophæus longicollis* was about the size of a greyhound. Its neck was like that of a swan, and its tail was of considerable length.

7. TANYSTROPHÆUS BAURI Cope. *Cœlurus bauri* Cope. American Naturalist, 1887, p. 368.

Almost as much of this species is preserved as of the last. There are no phalanges, but everything else is represented, including several cervical vertebræ, none of which are complete. There is a probable head of a tibia.

The differences are seen in the peculiarities of the cervical vertebræ and of the femur, and in the inferior size. The sides of the cervical centra are deeply and widely grooved on the posterior half, and the superior face of the neural arch is strongly grooved on each side on the anterior half. The femur is not so strongly grooved at the third trochanteric ridge on its exterior side, as in the *T. longicollis*.

		M.
Diameters of anterior face of third cervical	vertical	.010
	transverse	.0115
Width of do., including parapophyses		.017
Diameters of cervical centrum, behind	vertical	.0115
	transverse	.013
Length of dorsal vertebra		.030
Diameters do. posteriorly	transverse	.015
	vertical	.014
Length of sacrum		.073
Diameters of anterior sacral centrum, in front	vertical	.014
	transverse	.015
Diameters of head of pubis	anteroposterior	.032
	transverse	.010
Diameters head of ischium	anteroposterior	? .023
	transverse	.013
Diameters distal end ischium	anteroposterior	.020
	transverse	.013
Transverse diameter of femoral condyles		.032
Diameters head of tibia	anteroposterior	.024
	transverse	.018

The head of the *tibia* is trilobate posteriorly. The outline is anteroposteriorly sigmoid, the spine turning outwards and forming an acute angle. From this apex both borders are strongly sigmoid, the external commencing with concavity, the internal with convexity. The distal end of the ischium is oblique to the long axis of the bone, and its outline is triangular; the external convexity being stronger than in the *T. longicollis*.

The *sacrum* consists of four rather elongate centra, which have a subquadrate vertical section. A portion of an ilium adheres to it in the speci-

men, which is almost as large as that of the *T. longicollis*. If the ilium belongs to the same individual as the sacrum, the latter must belong to the *T. longicollis;* but I suspect that the association is accidental.

The diapophyses for the ilia are on the second, third and fourth sacral vertebræ. The second is directed forwards and upwards, the others backwards and upwards. There is a large deep fossa (or ? foramen) above the posterior halves of the second and third centra. The coössified bases of the diapophyses form a thin overhanging ledge.

8. TANYSTROPHÆUS WILLISTONI sp. nov.

This, the smallest of the species, is represented by an ilium, from which the ischiadic process has been broken away, and probably by some vertebræ and other bones. The latter can only be associated with the ilium on account of their appropriate size, since they were found with those of the two other species mingled together in one locality.

The ilium is at once to be distinguished from those of the species already named, by the equal elevation of the internal and external superior borders of the acetabulum. The latter is as widely open internally as externally, which is not the case with the other species. The external superior border, though more produced than the internal, is not so roof-like as in the others. The anterior process above the pubic process is compressed. The pubic surface is sigmoid in vertical section, even more strongly than in the other species. The superior plate of the ilium is much compressed.

Width of roof of acetabulum	.015
" " pubic surface	.0095
Length of " "	.008

The dorsal centrum may be that of a young animal, since the neural canal is larger than in the larger species, and the neural arch is not coössified. The median portion is not so contracted as in the other species, and its section is rounded quadrate. Articular faces a little wider than deep.

Length of centrum		.019
Diameters of centrum	vertical	.008
	transverse	.010

Dedicated to Professor S. W. Williston, of Yale College, the author of numerous important works on vertebrate palæontology.

Remarks.—From the above determinations a close parallelism between the Upper Keuper of Würtemberg and New Mexico may be discovered. In both the genera Belodon and Tanystrophæus are abundant, and the Aëtosaurus of the former is represented by the Typothorax of the latter. This association of such very diverse forms is good evidence of general identity of fauna, and is a sufficient basis for asserting taxonomic identity of the formations in the two regions.

EXPLANATION OF PLATES.

Plate I.

Bones of *Typothorax coccinarum* Cope, two-fifths natural size.

Fig. 1. A rib, from below.

Fig. 1*a*. The same with dermal bone, edge view.

Fig. 1*b*. The same, view of fractured extremity.

Fig. 2. Another dermoösseous band, one end wanting, from above.

Fig. 3. Femur, right side, from behind.

Fig. 3*a*. Do., proximal view.

Fig. 3*b*. Do., distal view.

Plate II.

Casts of brain-cases of *Belodon buceros* and *Alligator mississippiensis*, natural size.

Figs. 1–3. *Belodon buceros*.

Figs. 4–5. *Alligator mississippiensis*.

Fig. 1. Left side.

Fig. 2. Superior surface.

Fig. 3. Front view.

Fig. 4. Left side.

Fig. 5. Front view.

RE. Rhinencephalon.

PE. Prosencephalon.

ME. Mesencephalon.

Ep.E. Epencephalon (Cerebellum).

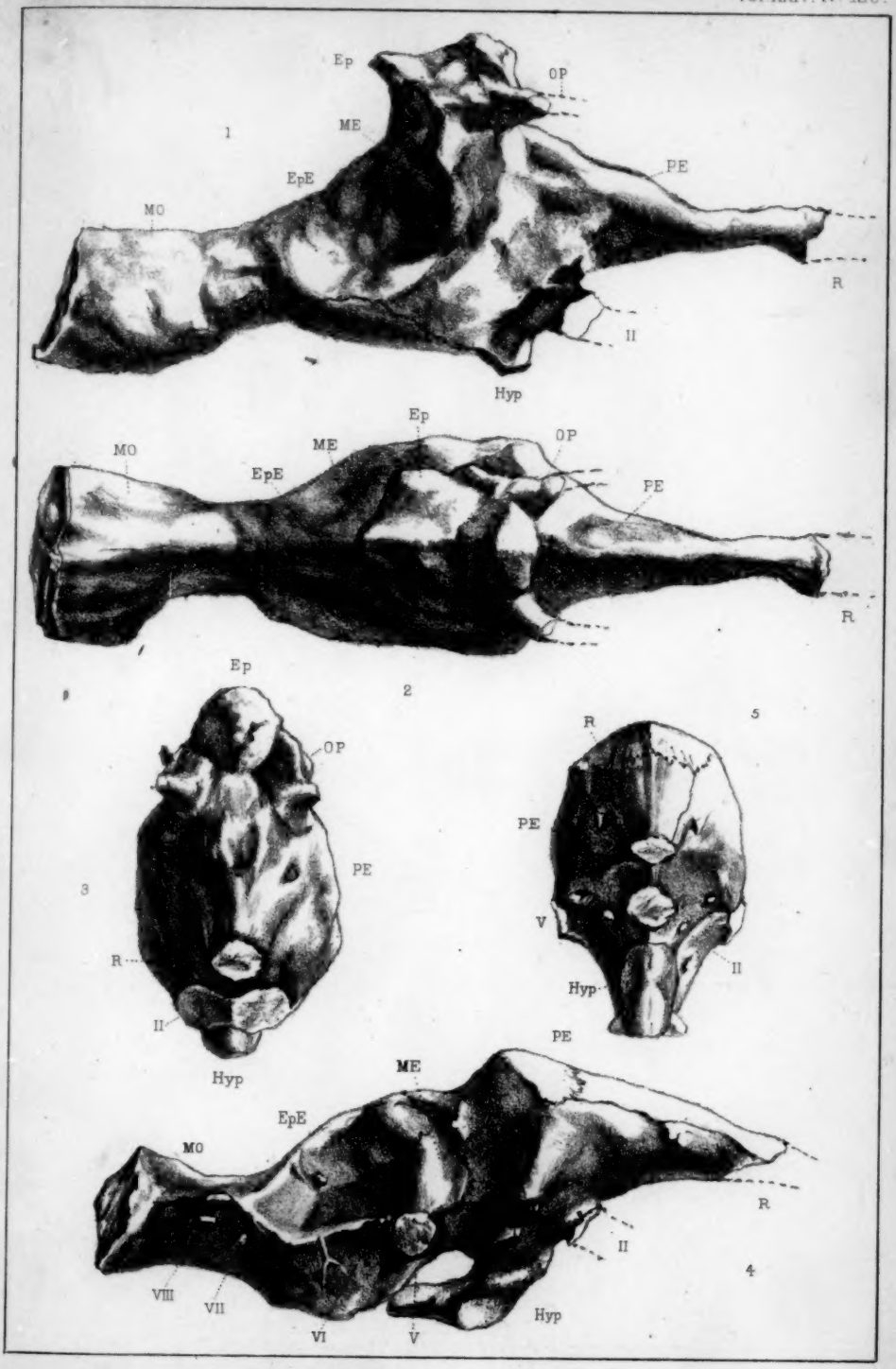
MO. Medulla oblongata.

Ep. Epiphysis.

Hyp. Hypophysis.

ii. Optic nerve; v. Trigeminus; vi. Abducens; viii. Facialis; viii. Auditorius.

OP. Orbitopineal process or nerve.



1-3 BELODON BUCEROS. 4-5. ALLIGATOR MISSISSIPPIENSIS ½.

TYPOTHORAX COCCINARUM COPE 86.

PLATE I.

T. SINCLAIR & SON, LITH. PHILA.

TYPOTHORAX COCCINARUM COPE ⅔.

Were the Toltecs an Historic Nationality?

By Daniel G. Brinton, M.D.

(*Read before the American Philosophical Society, Sept. 2, 1887.*)

In the first edition of my *Myths of the New World*,* published in 1868, I asserted that the story of the city of Tula and its inhabitants, the Toltecs, as currently related in ancient Mexican history, is a myth, and not history. This opinion I have since repeated in various publications,† but writers on pre-Columbian American civilization have been very unwilling to give up their Toltecs, and here lately M. Charnay has composed a laborious monograph to defend them.‡

Let me state the question squarely.

The orthodox opinion is that the Toltecs, coming from the north (-west or -east), founded the city of Tula (about forty miles north of the present city of Mexico) in the sixth century A.D.; that their State flourished for about five hundred years, until it numbered nearly four millions of inhabitants, and extended its sway from ocean to ocean over the whole of Central Mexico;§ that it reached a remarkably high stage of culture in the arts; that in the tenth or eleventh century it was almost totally destroyed by war and famine;‖ and that its fragments,

* *Myths of the New World.* By D. G. Brinton. Chap. vi, *passim.*

† Especially in *American Hero Myths, a Study in the Native Religions of the Western Continent*, pp. 35, 64, 82, etc. (Philadelphia, 1882).

‡ M. Charnay, in his essay, *La Civilisation Tolteque*, published in the *Revue d'Ethnographie*, Tome iv, p. 281, 1885, states his thesis as follows: "Je veux prouver l'existence du Toltèque que certains ont niée; je veux prouver que les civilisations Americaines ne sont qu'une seule et même civilisation; enfin, je veux prouver que cette civilisation est toltèque." I consider each of these statements an utter error. In his *Anciennes Villes du Nouveau Monde*, M. Charnay has gone so far as to give a map showing the migrations of the ancient Toltecs. As a translation of this work, with this map, has recently been published in this country, it appears to me the more needful that the baseless character of the Toltec legend be distinctly stated.

§ Ixtlilxochitl, in his *Relaciones Historicas* (in Lord Kingsborough's *Antiquities of Mexico*, Vol. ix, p. 333), says that during the reign of Topiltzin, last king of Tula, the Toltec sovereignty extended a thousand leagues from north to south and eight hundred from east to west; and in the wars that attended its downfall five million six hundred thousand persons were slain!!

‖ Sahagun (*Hist. de la Nueva España*, Lib. viii, cap. 5) places the destruction of Tula in the year 319 B. C.; Ixtlilxochitl (*Historia Chichmeca*, iii, cap. 4) brings it down to 969 A. D.; the *Codex Ramirez* (p. 25) to 1168; and so on. There is an equal variation about the date of founding the city.

escaping in separate colonies, carried the civilization of Tula to the south, to Tabasco (Palenque), Yucatan, Guatemala and Nicaragua. Quetzalcoatl, the last ruler of Tula, himself went to the south-east, and reappears in Yucatan as the culture-hero Cukulkan, the traditional founder of the Maya civilization.

This, I say, is the current opinion about the Toltecs. It is found in the works of Ixtlilxochitl, Veitia, Clavigero, Prescott, Brasseur de Bourbourg, Orozco y Berra, and scores of other reputable writers. The dispersion of the Toltecs has been offered as the easy solution of the origin of the civilization not only of Central America, but of New Mexico and the Mississippi valley.*

The opinion that I oppose to this, and which I hope to establish in this article, is as follows:

Tula was merely one of the towns built and occupied by that tribe of the Nahuas known as *Azteca* or *Mexica*, whose tribal god was Huitzilopochtli, and who finally settled at Mexico-Tenochtitlan (the present city of Mexico); its inhabitants were called Toltecs, but there was never any such distinct tribe or nationality; they were merely the ancestors of this branch of the Azteca, and when Tula was destroyed by civil and foreign wars, these survivors removed to the valley of Mexico and became merged with their kindred; they enjoyed no supremacy, either in power or in the arts; and the Toltec "empire" is a baseless fable. What gave them their singular fame in later legend was partly the tendency of the human mind to glorify the "good old times" and to merge ancestors into divinities, and especially the significance of the name Tula, "the Place of the Sun," leading to the confounding and identification of a half-forgotten legend with the ever-living light-and-darkness myth of the gods Quetzalcoatl and Tezcatlipoca.

To support this view, let us inquire what we know about Tula as an historic site.

Its location is on one of the great ancient trails leading from

*Since writing the above I have received from the Comte de Charencey a reprint of his article on *Xibalba*, in which he sets forth the theory of the late M. L. Angrand, that all ancient American civilization was due to two "currents" of Toltecs, the western, straight-headed Toltecs, who entered Anahuac by land from the north-west, and the eastern, flat-headed Toltecs, who came by sea from Florida. It is to criticise such vague theorizing that I have written this paper.

the north into the Valley of Mexico.* The ruins of the old town are upon an elevation about 100 feet in height, whose summit presents a level surface in the shape of an irregular triangle some 800 yards long, with a central width of 300 yards, the apex to the south-east, where the face of the hill is fortified by a rough stone wall.† It is a natural hill, overlooking a small muddy creek, called the *Rio de Tula*.‡ Yet this unpretending mound is the celebrated *Coatepetl*, Serpent-Mount, or Snake-Hill, famous in Nahuatl legend, and the central figure in all the wonderful stories about the Toltecs.§ The remains of the artificial tumuli and walls, which are abundantly scattered over the summit, show that, like the pueblos of New Mexico, they were built of large sun-baked bricks mingled with stones, rough or trimmed, and both walls and floors were laid in a firm cement, which was usually painted of different colors. Hence probably the name *Palpan*, "amid the colors," which tradition says was applied to these structures on the Coatepetl.‖ The stone-work,

* Motolinia, in his *Historia de los Indios de Nueva España*, p. 5, calls the locality "el puerto llamado Tollan," the pass or gate called Tollan. Through it, he states, passed first the Colhua and later the Mexica, though he adds that some maintain these were the same people. In fact, Colhua is a form of a word which means "ancestors;" *colli*, forefather, *no-col-huan*, my forefathers, *Colhuacan*, "the place of the forefathers," where they lived. In Aztec picture-writing this is represented by a hill with a bent top, on the "ikonomatic" system, the verb *coloa*, meaning to bend, to stoop. Those Mexica who said the Colhua preceded them at Tula, simply meant that their own ancestors dwelt there. The *Anales de Cuauhtitlan* (pp. 29, 33) distinctly states that what Toltecs survived the wars which drove them southward became merged in the Colhuas. As these wars largely arose from civil dissensions, the account no doubt is correct which states that others settled in Acolhuacan, on the eastern shore of the principal lake in the Valley of Mexico. The name means "Colhuacan by the water," and was the State of which the capital was Tetzcoco.

† This description is taken from the map of the location in M. Charnay's *Anciennes Villes du Nouveau Monde*, p. 83. The measurements I have made from the map do not agree with those stated in the text of the book, but are, I take it, more accurate.

‡ Sometimes called the *Rio de Montezuma*, and also the *Tollanatl*, water of Tula. This stream plays a conspicuous part in the Quetzalcoatl myths. It appears to be the same as the river *Atoyac* (= flowing or spreading water, *atl*, *toyaua*), or *Xipacoyan* (= where precious stones are washed, from *xiuitl*, *paca*, *yan*), referred to by Sahagun, *Hist. de la Nueva España*, Lib. ix, cap. 29. In it were the celebrated "Baths of Quetzalcoatl," called *Atecpanamochco*, "the water in the tin palace," probably from being adorned with this metal (*Anales de Cuauhtitlan*).

§ See the *Codex Ramirez*, p. 24. Why called Snake-Hill the legend says not. I need not recall how prominent an object is the serpent in Aztec mythology. The name is a compound of *coatl*, snake, and *tepetl*, hill or mountain, but which may also mean town or city, as such were usually built on elevations. The form *Coatepec* is this word with the postposition *c*, and means "at the snake-hill," or, perhaps, "at Snake-town."

‖ Or to one of them. The name is preserved by Ixtlilxochitl, *Relaciones Historicas*, in Kingsborough, *Mexico*, Vol. ix, p. 326. Its derivation is from *palli*, a color (root *pa*), and the postposition *pan*. It is noteworthy that this legend states that Quetzalcoatl in his

represented by a few broken fragments, appears equal, but not superior, to that of the Valley of Mexico. Both the free and the attached column occur, and figure-carving was known, as a few weather-beaten relics testify. The houses contained many rooms, on different levels, and the roofs were flat. They were no doubt mostly communal structures. At the foot of the Serpent-Hill is a level plain, but little above the river, on which is the modern village with its corn-fields.

These geographical particulars are necessary to understand the ancient legend, and with them in mind its real purport is evident.*

That legend is as follows: When the Azteca or Mexica—for these names were applied to the same tribe †—left their early home in Aztlan—which Ramirez locates in Lake Chalco in the Valley of Mexico, and Orozco y Berra in Lake Chapallan in Michoacan ‡—they pursued their course for some generations in

avatar as *Ce Acatl* was born in the Palpan, "House of Colors;" while the usual story was that he came from Tla-pallan, the place of colors. This indicates that the two accounts are versions of the same myth.

* There are two ancient Codices extant, giving in picture-writing the migrations of the Mexi. They have been repeatedly published in part or in whole, with varying degrees of accuracy. Orozco y Berra gives their bibliography in his *Historia Antigua de Mexico*, Tom. iii, p. 61, note. These Codices differ widely, and seem contradictory, but Orozco y Berra has reconciled them by the happy suggestion that they refer to sequent and not synchronous events. There is, however, yet much to do before their full meaning is ascertained.

† The name Aztlan is that of a place and Mexitl that of a person, and from these are derived *Aztecatl*, plural, *Azteca*, and *Mexicatl*, pl. *Mexica*. The Azteca are said to have left Aztlan under the guidance of Mexitl (*Codex Ramirez*). The radicals of both words have now become somewhat obscured in the Nahuatl. My own opinion is that Father Duran (*Hist. de Nueva España*, Tom. i, p. 19) was right in translating Aztlan as "the place of whiteness," *el lugar de blancura*, from the radical *iztac*, white. This may refer to the East, as the place of the dawn; but there is also a temptation to look upon Aztlan as a syncope of *a-izta-tlan*, = "by the salt water."

Mexicatl is a *nomen gentile* derived from *Mexitl*, which was another name for the tribal god or early leader Huitzilopochtli, as is positively stated by Torquemada (*Monarquia Indiana*, Lib. viii, cap. xi). Sahagun explains Mexitl as a compound of *metl*, the maguey, and *citli*, which means hare and grandmother (*Historia de Nueva España*, Lib. x, cap. 29). It is noteworthy that one of the names of Quetzalcoatl is *Meconetzin*, son of the maguey (Ixtlilxochitl, *Rel. Hist.*, in Kingsborough, Vol. ix, p. 328). These two gods were originally brothers, though each had divers mythical ancestors.

‡ Orozco y Berra, *Historia Antigua de Mexico*, Tom. iii, cap. 4. But Albert Gallatin was the first to place Aztlan no further west than Michoacan (*Trans. American Ethnolog. Society*, Vol. ii, p. 202). Orozco thinks Aztlan was the small island called Mexcalla in Lake Chapallan, apparently because he thinks this name means "houses of the Mexi;" but it may also signify "where there is abundance of maguey leaves," this delicacy being called *mexcalli* in Nahuatl, and the terminal *a* signifying location or abundance. (See Sahagun, *Historia de Nueva España*, Lib. vii, cap. 9.) At present, one of the smaller species of maguey is called *mexcalli*.

harmony; but at a certain time, somewhere between the eighth and the eleventh century of our era, they fell out and separated. The legend refers to this as a dispute between the followers of the tribal god Huitzilopochtli and those of his sister Malinalxochitl. We may understand it to have been the separation of two "totems." The latter entered at once the Valley of Mexico, while the followers of Huitzilopochtli passed on to the plain of Tula and settled on the Coatepetl. Here, says the narrative, they constructed houses of stone and of rushes, built a temple for the worship of Huitzilopochtli, set up his image and those of the fifteen divinities (gentes?) who were subject to him, and erected a large altar of sculptured stone and a court for their ball play.* The level ground at the foot of the hill they partly flooded by damming the river, and used the remainder for planting their crops. After an indeterminate time they abandoned Tula and the Coatepetl, driven out by civil strife and warlike neighbors, and journeyed southward into the Valley of Mexico, there to found the famous city of that name.

This is the simple narrative of Tulan, stripped of its contradictions, metaphors and confusion, as handed down by those highest authorities, the Codex Ramirez, Tezozomoc and Father Duran.† It is a plain statement that Tula and its Snake-Hill were merely one of the stations of the Azteca in their migrations —an important station, indeed, with natural strength, and one that they fortified with care, where for some generations, probably, they maintained an independent existence, and which the story-tellers of the tribe recalled with pride and exaggeration.

How long they occupied the site is uncertain.‡ Ixtlilxochitl

* It is quite likely that the very stone image figured by Charnay, *Anciennes Villes du Nouveau Monde*, p. 72, and the stone ring used in the *tlachtli*, ball play, which he figures, p. 73, are those referred to in the historic legend.

† The *Codex Ramirez*, p. 24, a most excellent authority, is quite clear. The picture-writing—which is really phonetic, or, as I have termed it, *ikonomatic*—represents the Coatepetl by the sign of a hill (*tepetl*) inclosing a serpent (*coatl*). Tezozomoc, in his *Cronica Mexicana*, cap. 2, presents a more detailed but more confused account. Duran, *Historia de las Indias de Nueva España*, cap. 3, is worthy of comparison. The artificial inundation of the plain to which the accounts refer probably means that a ditch or moat was constructed to protect the foot of the hill. Herrera says: "Çercaron de agua el cerro llamado Coatepec." *Decadas de Indias*, Dec. iii, Lib. ii, cap. 11.

‡ The *Annals of Cuauhtitlan*, a chronicle written in the Nahuatl language, gives 309 years from the founding to the destruction of Tula, but names a dynasty of only four rulers. Veitia puts the founding of Tula in the year 713 A. D. (*Historia de Nueva España*, cap. 23). Let us suppose, with the laborious and critical Orozco y Berra (notes to the *Codex Ramirez*, p. 210) that the Mexi left Aztlan A. D. 648. These three dates would fit

gives a list of eight successive rulers of the "Toltecs," each of whom was computed to reign at least fifty-two years, or one cycle; but it is noteworthy that he states these rulers were not of "Toltec" blood, but imposed upon them by the "Chichimecs." This does not reflect creditably on the supposed singular cultivation of the Toltecs. Probably the warrior Aztecs subjected a number of neighboring tribes and imposed upon them rulers.*

If we accept the date given by the *Codex Ramirez* for the departure of the Aztecs from the Coatepetl—A. D. 1168—then it is quite possible that they might have occupied the site for a couple of centuries or longer, and that the number of successive chieftains named by Ixtlilxochitl should not be far wrong. The destructive battles of which he speaks as preceding their departure—battles resulting in the slaughter of more than five million souls—we may regard as the grossly overstated account of some really desperate conflicts.

That the warriors of the Azteca, on leaving Tula, scattered over Mexico, Yucatan and Central America, is directly contrary to the assertion of the high authorities I have quoted, and also to most of the mythical descriptions of the event, which declare they were all, or nearly all, massacred.†

The above I claim to be the real history of Tula and its Serpent-Hill, of the Toltecs and their dynasty. Now comes the question, if we accept this view, how did this ancient town and

into a rational chronology, remembering that there is an acknowledged hiatus of a number of years about the eleventh and twelfth centuries in the Aztec records (Orozco y Berra, notes to *Codex Ramirez*, p. 213). The *Anales de Cuauhtitlan* dates the founding of Tula *after* that of Tlaxcallan, Huexotzinco and Cuauhtitlan (p. 29).

* As usual, Ixtlilxochitl contradicts himself in his lists of rulers. Those given in his *Historia Chichimeca* are by no means the same as those enumerated in his *Relaciones Historicas* (Kingsborough, *Mexico*, Vol. ix, contains all of Ixtlilxochitl's writings). Entirely different from both is the list in the *Anales de Cuauhtitlan*. How completely euhemeristic Ixtlilxochitl is in his interpretations of Mexican mythology is shown by his speaking of the two leading Nahuatl divinities Tezcatlipoca and Huitzilopochtli as "certain bold warriors" ("ciertos caballeros muy valerosos." *Relaciones Historicas*, in Kingsborough, Vol. ix, p. 326).

† See the note to page 3. But it is not at all likely that Tula was absolutely deserted. On the contrary, Herrera asserts that *after* the foundation of Mexico and the adjacent cities (despues de la fundacion de Mexico i de toda la tierra) it reached its greatest celebrity for skilled workmen. *Decadas de Indias*, Dec. iii, Lib. ii, cap. 11. The general statement is that the sites on the Coatepetl and the adjacent meadows were unoccupied for a few years—the *Anales de Cuauhtitlan* says nine years—after the civil strife and massacre, and then were settled again. The *Historia de los Mexicanos por sus Pinturas*, cap. 11, says, "y ansi fueron muertos todos los de Tula, que no quedó ninguno."

its inhabitants come to have so wide a celebrity, not merely in the myths of the Nahuas of Mexico, but in the sacred stories of Yucatan and Guatemala as well—which was unquestionably the case?

To explain this, I must have recourse to some of those curious principles of language which have had such influence in building the fabric of mythology. In such inquiries we have more to do with words than with things, with names than with persons, with phrases than with facts.

First about these names, Tula, Tollan, Toltec—what do they mean? They are evidently from the same root. What idea did it convey?

We are first struck with the fact that the Tula I have been describing was not the only one in the Nahuatl district of Mexico. There are other Tulas and Tollans, one near Ococingo, another, now San Pedro Tula, in the State of Mexico, one in Guerrero, San Antonio Tula in Potosi,* etc. The name must have been one of some common import. Herrera, who spells it *Tulo*, by an error, is just as erroneous in his suggestion of a meaning. He says it means "place of the tuna," this being a term used for the prickly pear.† But *tuna* was not a Nahuatl word; it belongs to the dialect of Haiti, and was introduced into Mexico by the Spaniards. Therefore Herrera's derivation must be ruled out. Ixtlilxochitl pretends that the name Tollan was that of the first chieftain of the Toltecs, and that they were named after him;‡ but elsewhere himself contradicts this assertion. Most writers follow the *Codex Ramirez*, and maintain that Tollan—of which Tula is but an abbreviation—is from *tolin*, the Nahuatl word for rush, the kind of which they made mats, and means "the place of rushes," or, where they grow.

The respectable authority of Buschmann is in favor of this derivation; but according to the analogy of the Nahuatl language, the "place of rushes" should be *Toltitlan* or *Tolinan*, and there are localities with these names.§

Without doubt, I think, we must accept the derivation of

* See Buschmann, *Ueber die Aztekischen Ortsnamen*, ss. 682, 788. Orozco y Berra, *Geografia de las Lenguas de Mejico*, pp. 248, 255.

† *Historia de las Indias Occidentales*, Dec. iii, Lib. ii, cap. 11.

‡ *Relaciones Historicas*, in Kingsborough's *Mexico*, Vol. ix, p. 392. Compare his *Historia Chichimeca*.

§ Buschmann, *Ueber die Aztekischen Ortsnamen*, ss. 682, 797.

Tollan given by Tezozomoc, in his *Cronica Mexicana*. This writer, thoroughly familiar with his native tongue, conveys to us its ancient form and real sense. Speaking of the early Aztecs, he says: "They arrived at the spot called Coatepec, on the borders of *Tonalan, the place of the sun.*"*

This name, Tonallan, is still not unusual in Mexico. Buschmann enumerates four villages so called, besides a mining town, *Tonatlan*.† "Place of the sun" is a literal rendering, and it would be equally accurate to translate it "sunny-spot" or "warm place" or "summer-place." There is nothing very peculiar or distinctive about these meanings. The warm, sunny plain at the foot of the Snake-Hill was called, naturally enough, Tonallan, syncopated to Tollan and thus to Tula.‡

But the literal meaning of Tollan—"Place of the Sun"—brought it in later days into intimate connection with many a myth of light and of solar divinities, until this ancient Aztec pueblo became apotheosized, its inhabitants transformed into magicians and demigods, and the corn-fields of Tula stand forth as fruitful plains of Paradise.

In the historic fragments to which I have alluded there is scant reference to miraculous events, and the gods play no part in the sober chronicle. But in the mythical cyclus we are at once translated into the sphere of the supernal. The Snake-

* *Cronica Mexicana*, cap. 1. "Partieron de allí y vinieron á la parte que llaman Coatepec, términos de Tonalan, lugar del sol." In Nahuatl *tonallan* usually means summer, sun-time. It is syncopated from *tonalli* and *tlan;* the latter is the locative termination; *tonalli* means warmth, *sunniness*, akin to *tonatiuh*, sun; but it also means soul, spirit, especially when combined with the possessive pronouns, as *to-tonal*, our soul, our immaterial essence. By a further syncope *tonallan* was reduced to Tollan or Tullan, and by the elision of the terminal semi-vowel, this again became Tula. This name may therefore mean "the place of souls," an accessory signification which doubtless had its influence on the growth of the myths concerning the locality.

It may be of some importance to note that Tula or Tollan was not at first the name of the town, but of the locality—that is, of the warm and fertile meadow-lands at the foot of the Contepetl. The town was at first called Xocotitlan, the place of fruit, from *xocotl*, fruit, *ti*, connective, and *tlan*, locative ending. (See Sahagun, *Historia de Nueva España*, Lib. x, cap. 29, secs. 1 and 12.) This name was also applied to one of the quarters of the city of Mexico when conquered by Cortes, as we learn from the same authority.

† Buschmann, *Ueber die Aztekischen Ortsnamen*, ss. 794, 797 (Berlin, 1852).

‡ The verbal radical is *tona*, to warm (hazer calor, Molina, *Vocabulario de la Lengua Mexicana*, s. v.); from this root come many words signifying warmth, fertility, abundance, the sun, the east, the summer, the day, and others expressing the soul, the vital principle, etc. (Siméon, *Dict. de la Langue Nahuatl*, s. v. *tonalli*.) As in the Algonkin dialects the words for cold, night and death are from the same root, so in Nahuatl are those for warmth, day and life. (Comp. Duponceau, *Mémoire sur les Langues de l'Amérique du Nord*, p. 327, Paris, 1836.)

Hill Coatepetl becomes the Aztec Olympus. On it dwells the great goddess "Our Mother amid the Serpents," *Coatlan Tonan*,* otherwise called "The Serpent-skirted," *Coatlicue*, with her children, The Myriad Sages, the *Centzon Huitznahua*.† It was her duty to sweep the Snake-Hill every day that it might be kept clean for her children. One day while thus engaged, a little bunch of feathers fell upon her, and she hid it under her robe. It was the descent of the spirit, the divine Annunciation. When the Myriad Sages saw that their mother was pregnant, they were enraged, and set about to kill her. But the unborn babe spake from her womb, and provided for her safety, until in due time he came forth armed with a blue javelin, his flesh painted blue, and with a blue shield. His left leg was thin and covered with the plumage of the humming-bird. Hence the name was given to him "On the left, a Humming-Bird," Huitzilopochtli.‡ Four times around the Serpent-Mountain did he drive the Myriad Sages, until nearly all had fallen dead before his dart, and the remainder fled far to the south. Then all the Mexica chose Huitzilopochtli for their god, and paid honors to the Serpent-Hill by Tula as his birthplace. §

* *Coatlan, to-nan*, from *coatl*, serpent; *tlan*, among; *to-nan*, our mother. She was the goddess of flowers, and the florists paid her especial devotion (Sahagun, *Historia*, Lib. ii, cap. 22). A precinct of the city of Mexico was named after her, and also one of the edifices in the great temple of the city. Here captives were sacrificed to her and to the Huitznahua. (Ibid., Lib. ii, Appendix. See also Torquemada, *Monarquia Indiana*, Lib. x, cap. 12.)

† *Centzon Huitznahua*, "the Four Hundred Diviners with Thorns." Four hundred, however, in Nahuatl means any indeterminate large number, and hence is properly translated myriad, legion. *Nahuatl* means wise, skillful, a diviner, but is also the proper name of the Nahuatl-speaking tribes; and as the Nahuas derived their word for south from *huitztli*, a thorn, the Huitznahua may mean "the southern Nahuas." Sahagun had this in his mind when he said the Huitznahua were goddesses who dwelt in the south (*Historia de Nueva España*, Lib. vii, cap. 5). The word is taken by Father Duran as the proper name of an individual, as we shall see in a later note.

‡ *Huitzilopochtli*, from *huitzilin*, humming-bird, *opochtli*, the left side or hand. This is the usual derivation; but I am quite sure that it is an error arising from the ikonomatic representation of the name. The name of his brother, Huitznahua, indicates strongly that the prefix of both names is identical. This, I doubt not, is from *huitz-tlan*, the south; *tlo* is from *iloa*, to turn; this gives us the meaning "the left hand turned toward the south." Orozco y Berra has pointed out that the Mexica regarded left-handed warriors as the more formidable (*Historia Antigua de Mexico*, Tom. i, p. 125). Along with this let it be remembered that the legend states that Huitzilopochtli was born in Tula and insisted on leading the Mexica toward the south, the opposition to which by his brother led to the massacre and to the destruction of the town.

§ This myth is recorded by Sahagun, *Historia de Nueva España*, Lib. iii, cap. 1, "On the Origin of the Gods." It is preserved with some curious variations in the *Historia de los Mexicanos por sus Pinturas*, cap. 11. When the gods created the sun they also formed

An equally ancient and authentic myth makes Huitzilopochtli one of four brothers, born at one time of the uncreated, bi-sexual divinity, the God of our Life, Tonacatecutli, who looms dimly at the head of the Aztec Pantheon. The brothers were the black and the white Tezcatlipoca and the fair-skinned, bearded Quetzalcoatl. Yet a third myth places the birthplace of Quetzalcoatl directly in Tula, and names his mother, Chimalman, a virgin, divinely impregnated, like Coatlicue, by the descending spirit of the Father of All.*

Tula was not only the birthplace, but the scene of the highest activity of all these greatest divinities of the ancient Nahuas. Around the Coatepetl and on the shores of the Tollanatl—"the Water of Tula"—as the stream is called which laves the base of the hill, the mighty struggles of the gods took place which form the themes of almost all Aztec mythology. Tulan itself is no longer the hamlet of rush houses at the foot of the Coatepec, surmounted by its pueblo of rough stone and baked brick. It is a glorious city, founded and governed by Quetzalcoatl himself, in his first avatar as Hueman, the strong-handed. "All its structures were stately and gracious, abounding in ornaments. The walls within were incrusted with precious stones or finished in beautiful stucco, presenting the appearance of a rich mosaic. Most wonderful of all was the temple of Quetzalcoatl. It had four chambers, one toward the east finished in pure gold, another toward the west lined with torquoise and emeralds, a third toward the south decorated with all manner of delicate sea-shells, and a fourth to the north resplendent with red jasper and

four-hundred men and five women for him to eat. At the death of the women their robes were preserved, and when the people carried these to the Coatepec, the five women came again into being. One of these was Coatlicue, an untouched virgin, who after four years of fasting placed a bunch of white feathers in her bosom, and forthwith became pregnant. She brought forth Huitzilopochtli completely armed, who at once destroyed the Huitznahua. Father Duran translates all of this into plain history. His account is that when the Aztecs had occupied Tollan for some time, and had fortified the hill and cultivated the plain, a dissension arose. One party, followers of Huitzilopochtli, desired to move on; the other, headed by a chieftain, Huitznahua, insisted on remaining. The former attacked the latter at night, massacred them, destroyed the water-dams and buildings, and marched away (*Historia de las Indias de Nueva España*, Tom. i, pp. 25, 26). According to several accounts, Huitznahua was the brother of Huitzilopochtli. See my *American Hero Myths*, p. 81.

* I have discussed both these accounts in my *American Hero Myths*, chap. iii, and need not repeat the authorities here.

shells."* The description of other buildings, equally wondrous, have been lovingly preserved by the ancient songs.† What a grief that our worthy friend, M. Charnay, digging away in 1880 on the Coatepec, at the head of a gang of forty-five men, as he tells us,‡ unearthed no sign of these ancient glories, in which, for one, he fully believes! But, alas! I fear that they are to be sought nowhere out of the golden realm of fancy and mythical dreaming.

Nor, in that happy age, was the land unworthy such a glorious city. Where now the neglected corn-patches surround the shabby huts of Tula, in the good old time "the crops of maize never failed, and each ear was as long as a man's arm; the cotton burst its pods, not white only, but spontaneously ready dyed to the hand in brilliant scarlet, green, blue and yellow; the gourds were so large that they could not be clasped in the arms; and birds of brilliant plumage nested on every tree!"

The subjects of Quetzalcoatl, the Toltecs, were not less marvelously qualified. They knew the virtues of plants and could read the forecasts of the stars; they could trace the veins of metals in the mountains, and discern the deposits of precious stones by the fine vapor which they emit; they were orators, poets and magicians; so swift were they that they could at once be in the place they wished to reach; as artisans their skill was unmatched, and they were not subject to the attacks of disease.

The failure and end of all this goodly time came about by a battle of the gods, by a contest between Tezcatlipoca and Huitzilopochtli on the one hand, and Quetzalcoatl on the other. Quetzalcoatl refused to make the sacrifices of human beings as required by Huitzilopochtli, and the latter, with Tezcatlipoca, set about the destruction of Tula and its people. This was the

* The most highly-colored descriptions of the mythical Tula are to be found in the third and tenth book of Sahagun's *Historia de Nueva España*, in the *Anales de Cuauhtitlan*, and in the various writings of Ixtlilxochitl. Later authors, such as Veytia, Torquemada, etc., have copied from these. Ixtlilxochitl speaks of the "legions of fables" about Tulan and Quetzalcoatl which even in his day were still current ("otras trescientas fabulas que aun todavia corren," *Relaciones Historicas*, in Kingsborough, *Mexico*, Vol. ix, p. 332).

† In the collection of *Ancient Nahuatl Poems*, which forms the seventh volume of my *Library of Aboriginal American Literature*, p. 104, I have printed the original text of one of the old songs recalling the glories of Tula, with its "house of beams," *huapalcalli*, and its "house of plumed serpents," *coallaquetzalli*, attributed to Quetzalcoatl.

‡ *Les Anciennes Villes du Nouveau Monde*, p. 84 (Paris, 1885).

chosen theme of the later Aztec bards. What the siege of Troy was to the Grecian poets, the fall of Tula was to the singers and story-tellers of Anahuac—an inexhaustible field for imagination, for glorification, for lamentation. It was placed in the remote past—according to Sahagun, perhaps the best authority, about the year 319 before Christ.* All arts and sciences, all knowledge and culture, were ascribed to this wonderful mythical people, and wherever the natives were asked concerning the origin of ancient and unknown structures, they would reply, "The Toltecs built them."†

They fixedly believed that some day the immortal Quetzalcoatl would appear in another avatar, and would bring again to the fields of Mexico the exuberant fertility of Tula, the peace and happiness of his former reign, and that the departed glories of the past should surround anew the homes of his votaries.‡

I have elsewhere so fully represented this phase of the mythical cyclus that I need not emphasize it further; nor need I explain the significance of these myths as revealed to us by an application of the principles of comparative mythology; for that, too, would be repeating what I have already published in ample detail.

What I wish to point out in clear terms is the contrast between the dry and scanty historic narrative which shows Tula with its Snake-Hill to have been an early station of the Azteca, occupied in the eleventh and twelfth century by one of their clans, and the monstrous myth of the later priests and poets, which makes of it a birthplace and abode of the gods, and its inhabitants the semi-divine conquerors and civilizers of Mexico and Central America. For this latter fable there is not a vestige of solid foundation. The references to Tula and

* *Historia de Nueva España*, Lib. viii, cap. 5.

† Father Duran relates, "Even to this day, when I ask the Indians, 'Who created this pass in the mountains? Who opened this spring? Who discovered this cave? or, Who built this edifice?' they reply, 'The Toltecs, the disciples of Papa.'" *Historia de las Indias de Nueva España*, cap. 79. *Papa*, from *papachtic*, the bushy-haired, was one of the names of Quetzalcoatl. But the earlier missionary, Father Motilinia, distinctly states that the Mexica invented their own arts, and owed nothing to any imaginary teachers, Toltecs or others. "Hay entre todos los Indios muchos oficios, y de todos dicen *que fueron inventores los Mexicanos.*" *Historia de los Indios de la Nueva España*, Tratado iii, cap. viii.

‡ Quetzalcoatl announced that his return should take place 5012 years after his final departure, as is mentioned by Ixtlilxochitl (in Kingsborough, *Mexico*, Vol. ix, p. 332). This number has probably some mystic relation to the calendar.

the Toltecs in the *Chronicles of the Mayas* and the *Annals of the Kakchiquels* are loans from the later mythology of the Nahuas. It is high time for this talk about the Toltecs as a mighty people, precursors of the Azteca, and their instructors in the arts of civilization, to disappear from the pages of history. The residents of ancient Tula, the Tolteca, were nothing more than a sept of the Nahuas themselves, the ancestors of those Mexica who built Tenochtitlan in 1325. This is stated as plainly as can be in the Aztec records, and should now be conceded by all. The mythical Tula, and all its rulers and inhabitants, are the baseless dreams of poetic fancy, which we principally owe to the Tezcucan poets.

In conclusion, I have no hesitation in repeating the words which I printed some years ago, and which gave considerable offence in certain quarters: "Is it not time that we dismiss, once for all, these American myths from the domain of historical traditions? Why should we try to make an enlightened ruler of Quetzalcoatl, a cultured nation of the Toltecs, when the proof is of the strongest that they are the fictions of mythology? Let it be understood hereafter that whoever uses these names in an historic sense betrays an ignorance of the subject he handles, which, were it in the better-known field of Aryan or Egyptian lore, would convict him of not meriting the name of scholar."*

* *American Hero Myths*, p. 35. The only writer on ancient American history before me who has wholly rejected the Toltecs is, I believe, Albert Gallatin. In his able and critical study of the origin of American civilization (*Transactions of the American Ethnological Society*, Vol. i, p. 203) he dismissed them entirely from historical consideration with the words: "The tradition respecting the Toltecs ascends to so remote a date, and is so obscure and intermixed with mythological fables, that it is impossible to designate either the locality of their primitive abodes, the time when they first appeared in the vicinity of the Valley of Mexico, or whether they were preceded by nations speaking the same or different languages." Had this well-grounded skepticism gained the ears of writers since 1845, when it was published, we should have been saved a vast amount of rubbish which has been heaped up under the name of history.

Dr. Otto Stoll (*Guatemala; Reisen und Schilderungen*, ss. 408, 409, Leipzig, 1886) has joined in rejecting the ethnic existence of the Toltecs. As in later Nahuatl the word *toltecatl* meant not only "resident of Tollan," but also "artificer" and "trader," Dr. Stoll thinks that the Central American legends which speak of "Toltecs" should be interpreted merely as referring to foreign mechanics or pedlars, and not to any particular nationality. I quite agree with this view.

PROC. AMER. PHILOS. SOC. XXIV. 126. 2E. PRINTED OCT. 22, 1887.

Biela's Comet and the Large Meteors of November 27–30. By Professor Daniel Kirkwood.

(*Read before the American Philosophical Society, September 2, 1887.*)

The well-known catalogue of Greg, published in the Report of the British Association for 1860, p. 115 *et seq.*, designates the last days of November as one of the dates at which an unusual number of fire-balls and meteoric stones had fallen since the commencement of the nineteenth century. In the Danville Quarterly Review for December, 1861, the gradual dissolution of Biela's comet was suggested as the source of those periodic displays,* and the same theory was again advanced in the author's "Meteoric Astronomy" (1867), pp. 54, 121, and 126–129. The suggestion has also been made independently by others.

We give below the most distinguished star showers derived from the scattered portions of Biela's comet :—

1798. 7 December; recognized as Andromedes by Newton.
1830. 7 December; Quetelet's catalogue.
1838. 5 to 7 December; recognized by Newton.
1850. 29 November; Quetelet.
1872. 27 November.
1885. 27 November.

From 1798 to 1885, we have eighty-seven years $= 6.692 \times 13$; and the series is harmonized in the following scheme :—

$$\begin{aligned} 1798 \text{ to } 1838 &= 40 \text{ years} = 6 \times 6.66 + \\ 1830 \text{ to } 1850 &= 20 \text{ "} = 3 \times 6.66 + \\ 1838 \text{ to } 1872 &= 34 \text{ "} = 5 \times 6.80. \\ 1872 \text{ to } 1885 &= 13 \text{ "} = 2 \times 6.50. \end{aligned}$$

The dates, it will be observed, indicate considerable extension of the cluster, or rather, perhaps, the existence of several groups.

The remarkable fall of meteoric iron during the shower of Bielids on the 27th of November, 1885,† at once suggests the inquiry whether traces of the same period can be found in the recurrence of fire-balls and aerolites at the identical epoch. The following dates, except the last, are all derived from the catalogue of Mr. R. P. Greg :—

1809. 29 November; a fireball at Munich.
1810. 28 November, 9.30 P. M.; an aerolitic meteor at Cape Matapan.

* "The division of Biela's comet into two distinct parts suggests several interesting questions in cometary physics. * * * May not the force, whatever it is, that has produced *one* separation, again divide the parts? and may not this action continue until the fragments become invisible? According to the theory now generally received, the periodic phenomena of shooting stars are produced by the intersections of the orbits of such nebulous bodies with the earth's annual path. * * * May not our periodic meteors be the *débris* of ancient but now disintegrated comets whose matter has become distributed around their orbits?"—*Danville Quarterly Review*, Dec., 1861, p. 637.

† Amer. Journ. of Sci., March, 1887.

1820. 29 November; a very brilliant meteor at Cosenzo, Ionian Isles.
1821. 28 November; a fireball at Naples.
1821. 30 November; a fireball at Delitzsch.
1822. 30 November, before sunset; a fall of several aerolites at Futtehpore, Doab, India.
1823. 27 November; a fireball at Naples.
1824. 27 November; a fireball as large apparently as the moon, at Prague.
1833. End of November; a fall of aerolites by which a person was killed at Kandahar, Afghanistan.
1834. 29 November; a stone-fall at Raffaten, Hungary.
1834. 30 November; a fireball at Naples.
1839. 29 November, before sunset; a large fireball at Naples.
1842. 30 November; a shower of meteoric stones; specific gravity 3.36; N. E. of Ahmedabad.
1847. 29 November; a brilliant fireball at Bonn.
1848. 29 November; a fireball at Lincolnshire.
1850. 28 November; a fireball at Nottingham.
1850. 29 November; a fireball at London, Oxford, etc.
1850. 30 November; a stone-fall in India.
1859. 28 November; a brilliant detonating meteor, S. W. of Bohemia.
1885. 27 November; the fall of meteoric iron in Mexico (Am. Journ. Sci., Mar., 1887).

These twenty falls may be arranged as follows:—

1809 to 1822	= 13	years	= 2 × 6.50.
1810 to 1823	= 13	"	= 2 × 6.50.
1820 to 1833	= 13	"	= 2 × 6.50.
1821 to 1834	= 13	"	= 2 × 6.50.
1822 to 1842	= 20	"	= 3 × 6.66.
1824 to 1850	= 26	"	= 4 × 6.50.
1834 to 1847	= 13	"	= 2 × 6.50.
1822 to 1848	= 26	"	= 4 × 6.50.
1839 to 1859	= 20	"	= 3 × 6.66.
1859 to 1885	= 26	"	= 4 × 6.50.

The period is apparently well marked, though facts, as with the associated shooting stars, indicate the existence of several clusters moving in orbits very nearly identical. The period is short, thus affording frequent opportunities for studying the group—one of the most interesting with which we are acquainted. The next return may be expected in 1892. It will, of course, be carefully observed.

The comet of Biela was first observed in 1772, but previous traces of its *débris* may not be impossible. Instance the great meteor of December 5, 1762, and the fall of shooting stars on December 5, 1741, referred to in Quetelet's catalogue.

Notices of New Fresh-water Infusoria. By Alfred C. Stokes, M.D., Trenton, N. J.

(*Read before the American Philosophical Society, September 16th, 1887.*)

Hexamita spiralis, sp. nov. Fig. 1.

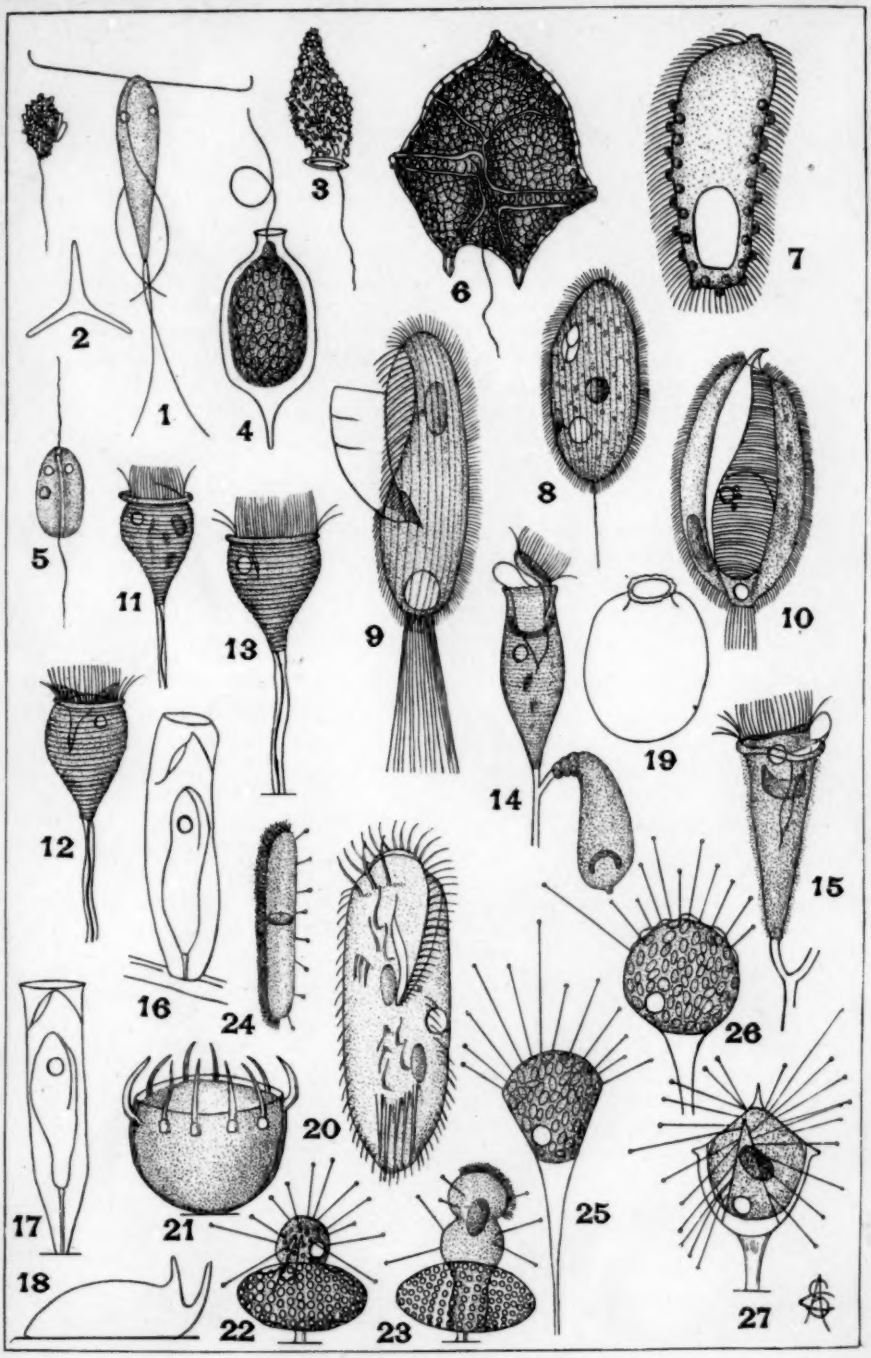
Body elongate obovate, about four times as long as broad, the anterior extremity rounded, the posterior obtusely pointed; anterior flagella four in number, vibratile, arising close together, their length diverse but exceeding that of the body, the two shortest extended opposite each other at right angles to the body, their distal extremities curved forward; the remaining two extending backward, each forming a long, loose spiral; trailing flagella two, arising from the tip of the posterior extremity, and exceeding the body in length; contractile vesicles two, situated opposite each other in the anterior body-half; nucleus obscure. Length of body, $\frac{1}{2\,5\,0}$ inch. *Hab.*—The intestinal canal of the tadpole of the common toad. Movements by rapid rotation on the longitudinal axis.

This differs from previously observed species in the presence of two contractile vesicles, and in the spiral disposition of two of the anterior flagella.

Petalomonas dorsalis, sp. nov. Fig. 2; diagram.

Body broadly ovate or suborbicular, colorless, transparent, the length but slightly exceeding the breadth; the anterior extremity the narrower, evenly or obliquely rounded, occasionally obliquely truncate; posterior border rounded, sometimes emarginate; dorsal surface longitudinally traversed by a central, strongly compressed keel-like and upright plane, or broad wing, the superior margin of which is evenly convex; ventral surface somewhat concave, a transverse optic section of the body presenting a triradiate appearance, the re-entering, dorso-lateral and ventral angles rounded; oral fossa conspicuous, from which apparently issues a flagellum subequal to the body in length; nucleus subcircular in outline, placed near the centre of the left-hand body margin; contractile vesicle single, small, located on the left-hand side of the dorsal ala near the body centre; endoplasm coarsely granular. Length of body, $\frac{1}{6\,5\,0}$ to $\frac{1}{6\,0\,0}$ inch. *Hab.*—Standing pond water.

This is readily recognizable from *P. carinata*, for which it might perhaps be mistaken, by its much larger size, and by the very conspicuously developed centro-dorsal, upright plane. In *P. carinata* the dorsal elevation is low and ridge-like, and although the lateral surfaces of this part are usually evenly sloping or slightly convex, they are at times noticeably concave. In *P. dorsalis* the dorsal ala is usually as high as one-half the width of the body. The part seems especially liable to deformity, often being observed to be variously indented, or distorted and developed to one side or the other of its normal central position.



Fresh-water Infusoria.—Stokes.

Petalomonas sulcata, sp. nov.

Body ovate, colorless, transparent, depressed, less than twice as long as broad, the surface traversed longitudinally, sometimes in a slightly oblique direction, by from eight to ten keel-like ridges, the intervening spaces being concave; anterior extremity narrowly rounded; the posterior truncate, with one, sometimes two, subcentral acuminations apparently formed by the terminal union of the longitudinal carinations; flagellum subequal to the body in length; nucleus and single contractile vesicle on opposite sides of the anterior body-half; endoplasm granular posteriorly. Length of body, $\frac{1}{750}$ inch. *Hab.*—Pond water. Movements not rapid, the oral aperture usually in contact with the submerged object, the flagellum directed in advance, the anterior extremity alone vibrating.

Urceolopsis (*Urceolus*; *οψις*), gen. nov.

Animalcules free-swimming, flask-shaped, soft, flexible and elastic, the entire cuticular surface more or less covered by adherent, irregular and angular sand grains; otherwise essentially as in *Urceolus*.

Urceolopsis sabulosa, sp. nov. Fig. 3.

Urceolus sabulosus, Stokes; Am. Monthly Micr. Journ., vii, May, 1886.

Body flask-shaped, soft, flexible, elastic, normally compressed and somewhat gibbous, about twice as long as broad, widest centrally, obtusely pointed posteriorly, the entire surface more or less covered, often almost concealed, by adherent, irregular and angular sand grains; anterior extremity constricted to form a short neck-like prolongation, the circular border thickened, expanded, and obliquely truncate; flagellum large, equaling or exceeding the body in length; nucleus not observed; contractile vesicle (?) single, laterally placed near the anterior extremity; pharynx apparently extending to near the body-centre. Length of body, $\frac{1}{500}$ inch. *Hab.*—Fresh water with Algæ.

Trachelomonas urceolata, sp. nov. Fig. 4.

Lorica vasiform, about twice as long as broad, the lateral margins slightly flattened, anteriorly produced in a short, subcylindrical neck, the aperture slightly everted, truncate, not oblique; posterior extremity not inflated, produced in an acuminate, tail-like prolongation; endoplasm enclosing numerous, probably amylaceous, corpuscles. Length of lorica, $\frac{1}{500}$ inch. *Hab.*—Pond water.

Trachelomonas verrucosa, sp. nov.

Lorica subspherical, colorless, the entire surface covered with minute, hemispherical elevations; anterior extremity slightly emarginate. Length and breadth, $\frac{1}{1000}$ inch. *Hab.*—Pond water, with Algæ.

Trachelomonas acanthostoma, sp. nov.

Lorica subspherical, brown, the anterior extremity bearing two more or less irregular rows of short, conical spines encircling the orifice, which is not produced, the remaining surface punctate; endoplasm apparently vacuolar. Length, $\frac{1}{500}$ inch. *Hab.*—Pond water.

Anisonema solenota, sp. nov. Fig. 5.

Body sub-elliptical, depressed, less than twice as long as broad, slightly narrowed at the anterior extremity; the posterior border rounded; the frontal margin slightly and narrowly truncate; ventral surface flat, the dorsal longitudinally traversed by a subcentral depression or groove; oral aperture distinct; flagella diverse in length, the vibratile appendage about as long as the body, the trailing twice that length; contractile vesicle double, situated opposite to each other in the anterior body-half, near the median groove; nucleus single, subspherical, subcentrally placed near the left-hand body-margin; endoplasm colorless, transparent. Length, $\frac{1}{1000}$ inch. *Hab.*—Standing pond water.

Protoperidinium limbatum, sp. nov. Fig. 6.

Carapace rhomboidal, depressed, little longer than broad, the postero-lateral margins produced in two, short, acuminate, horn-like processes, the posterior border concave; ventral surface flattened, with a central, longitudinal depression; surface facetted and minutely reticulated, the margins of the carapace and of the equatorial groove having a narrow, colorless, projecting, flattened and reticulate border; flagellum of the lateral groove spiral. Length, $\frac{1}{500}$ inch. *Hab.*—Marsh water, with sphagnum; color, yellow.

Holophrya ornata, sp. nov. Fig. 7.

Body obovate, compressed, slightly curved toward one side, less than three times as long as broad, the anterior extremity rounded, the posterior truncate; cuticular surface not striate, entirely ciliate; the cilia long and fine; oral aperture eccentric, the borders slightly protruding; lateral margins and posterior extremity ornamented by two rows of cuticular, rounded elevations, the series beginning at the middle third of one lateral border, and continued through the middle third of the opposite region, the constituent elevations of one series being alternate with those of the other; contractile vesicle single, large, near the posterior extremity; nucleus obscure; endoplasm coarsely granular. Length, about $\frac{1}{150}$ inch. *Hab.*—Standing pond water. Movements rotatory on the longitudinal axis.

Saprophilus (*σαπροφιλος*), gen. nov.

Animalcules free-swimming, holotrichous, ovate, soft, flexible and changeable in shape: general cuticular surface clothed with fine vibratile cilia, a single, long, flexible seta projecting from the posterior extremity; oral aperture ventral, supplemented by a vibratile and retractile hood-like membrane.

Saprophilus agitatus, sp. nov. Fig. 8.

Body ovate, compressed, about twice as long as broad, the posterior extremity rounded, the antero-ventral border obliquely truncate; cuticular surface longitudinally striate, the cilia short and fine; oral aperture ovate, ventral, at a short distance from the anterior extremity; the hood-like membrane narrow, widest posteriorly, narrowing to its anterior termination; contractile vesicle single, in the posterior body-half; nucleus subspherical, subcentrally placed. Length of body, $\frac{1}{750}$ to $\frac{1}{850}$ inch. *Hab.*—An infusion containing much decaying animal matter. Reproduction by transverse fission.

The hood-like velum resembles in character and function the oral appendage of *Pleuronema*, widely differing, however, in its vibratile movements, *Pleuronema* having only the power to lower and raise the organ, while the present form possesses the additional ability to rapidly vibrate the appendage. When retracted the latter is, similarly with the hood in *Pleuronema*, folded and stowed away about the posterior and lateral margins of the mouth.

The body is extremely soft, and quite changeable in shape, the latter, however, usually consisting chiefly in the assumption of a subspherical form. It has the power to force itself through small orifices, the body-sarcode flowing almost as freely as a semi-fluid substance.

These animalcules are essentially scavengers, greedily appropriating decaying animal fragments, swarming in crowds around and within the dead bodies of various small aquatic animals. Within the body of a dead *Gammarus* they were crowded in profusion, there rapidly undergoing reproductive fission, the process being probably hastened by the abundance of stimulating food.

Bothrostoma (*βοθρος*; *στομα*), gen. nov.

Animalcules free-swimming, heterotrichous, ovate, soft and flexible; peristome-field a more or less obliquely directed longitudinal depression, situated on the left-hand side of the body, extending beyond the body-centre, and continued inward as a short, ciliated, pharyngeal passage; the left-hand border of the peristome bearing a series of large cilia, the posterior portion of the right-hand margin supporting an undulating membrane; a cluster of long setose cilia projecting from the posterior extremity; contractile vesicle and nucleus conspicuous; anal aperture postero-terminal. Inhabiting fresh water.

Bothrostoma undulans, sp. nov. Fig. 9.

Body ovate, about two and one-half times as long as broad, colorless, soft and changeable in shape, the anterior extremity obtusely pointed, the posterior border truncate; cuticular surface longitudinally striate; peristome-field extending obliquely inwards beyond the body-centre; undulating membrane large, often resembling a long anteriorly curved seta, extending from the oral aperture to within one-third of the body-length of the anterior extremity; oral aperture at the posterior termination of the peristome, ovate; pharynx short, ciliate, infundibuliform; posterior setose cilia long and conspicuous; nucleus ovate, situated in the anterior body-half; contractile vesicle large, single, spherical, placed near the posterior extremity. Length of body, $\frac{1}{165}$ inch. *Hab.*—Standing pond water.

Hymenostoma magna, sp. nov. Fig. 10.

Body ovate, depressed, about twice as long as broad, the dorsal surface convex, the ventral flattened and chiefly occupied by the wide, adoral depression or groove which extends from the frontal border almost to the posterior extremity, the latter slightly produced and truncate, a broad tuft of larger cilia fringing the truncation; anterior border narrow, obliquely rounded; left-hand margin of the peristome bearing a series of long, fine cilia, directed across the adoral depression, the left-hand border furnished with an undulating membrane, widest anteriorly and projecting beyond the frontal body-margin as a sinistrally directed, concave acumination; oral aperture near the posterior extremity of the peristome; nucleus ovate, slightly curved, located posteriorly on the right-hand side of the body; contractile vesicle double, one near the posterior extremity, the other near the right-hand side of the body-centre, and formed, after systole, by the coalescence of several small vacuoles; cuticular surface fine striate longitudinally. Length of body, $\frac{1}{225}$ inch. *Hab.*—Standing pond water. Movement a rapid often backward revolution on the longitudinal axis.

This, the second known member of the genus, is readily distinguishable from *H. hymenophora* by the larger body, it being about twice as large as the last mentioned species, by the posterior truncation with its ciliary fringe, and by the form of the peristomal membrane, with its anterior projecting acumination. As in *H. hymenophora* the food masses collect in the left-hand side of the body.

Conjugation has been observed, union taking place between the ventral surfaces of the right-hand body-margins.

Vorticella pusilla, sp. nov. Fig. 11.

Body conical-campanulate, less than twice as long as broad, widest anteriorly, tapering thence to the pedicle; constricted immediately beneath the peristome; cuticular surface transversely striate; peristome equaling

the body-centre in width, the border thickened; pedicle from five to six times as long as the body; nucleus apparently ovate, anteriorly placed; contracted body subspherical, invaginating the extremity of the pedicle. Length of extended body, $\frac{1}{130}$ inch. *Hab.*—Pond water; attached to rootlets of *Lemna*. Solitary.

Vorticella mollis, sp. nov.

Body conical campanulate, somewhat changeable in shape, widest anteriorly, tapering posteriorly, the length scarcely exceeding the width; peristome broad, flattened, crateriform, equaling in width the body-length, the border not revolute; cuticular surface very minutely tuberculate; contractile vesicle double; pedicle from sixteen to eighteen times as long as the body; contracted body subspherical. Length of the extended zooid, $\frac{1}{600}$ inch. *Hab.*—Pond water; attached to rootlets of *Lemna*. Solitary.

Vorticella aqua-dulcis, sp. nov. Fig. 12.

Body ovate or pyriform, very slightly changeable in shape, less than twice as long as broad, slightly constricted beneath the peristome border, the cuticular surface strongly and conspicuously striate transversely; peristome more than one-half the body-centre in breadth, but not equaling it, the border thickened, not everted; ciliary disc obliquely elevated; pedicle from two to three times as long as the body. Length of body, $\frac{1}{130}$ inch. *Hab.*—Fresh water; attached to rootlets of *Lemna*. Solitary, or few together. Contracted body obovate.

Vorticella platysoma, sp. nov. Fig. 13.

Body ovate or pyriform, less than twice as long as broad, the anterior body region subspherical, the posterior tapering to the pedicle; cuticular surface transversely striate; peristome equaling the body-centre in width, the border revolute; the ciliary disc not elevated; nucleus band-like, curved, transversely placed in the anterior body-half; pedicle seldom exceeding the body in length. Length of body, $\frac{1}{125}$ inch. *Hab.*—Pond water; attached to Algæ.

Opercularia allensi, sp. nov. Fig. 14.

Bodies elongate-fusiform or subvasiform, more than three times as long as broad, widest centrally, tapering posteriorly to the pedicle, constricted beneath the peristome, the cuticular surface very finely striate transversely; peristome border everted, minutely crenulate; ciliary disc very obliquely exerted; ciliary circles two; membranous collar large and conspicuous; nucleus band-like, short, curved, transversely placed in the anterior body-half; contracted zooid suddenly pendent, obovate, usually

with two or more posterior annulations, and always exhibiting at the anterior border a short, but conspicuous snout-like prolongation; pedicle profusely and dichotomously branching, longitudinally striate, annulate irregularly and at wide intervals, the ultimate divisions very short. Length of body, $\frac{1}{100}$ inch; height of entire colony, $\frac{1}{25}$ inch. *Hab.*—Pond water; attached to Algæ and various aquatic plants.

At first glance this closely resembles *O. nutans* (Ehr.) Stein, great differences being discernible, however, on slight examination. In *O. nutans* the pedicle is strongly and conspicuously annulate; here the annulations are absent or few in number and irregularly placed. The zooids are here transversely striate, while in *O. nutans* they are presumably smooth. In size the two forms are also widely and distinctly different, the bodies of *O. nutans* measuring only $\frac{1}{150}$ inch in length, while in *O. allensi* they are almost twice as large; the height of the entire colony of the former is from $\frac{1}{14}$ to $\frac{1}{9}$ inch, an enormous altitude in comparison with the $\frac{1}{25}$ inch of *O. allensi*. In their contracted state their resemblance is very close.

Opercularia vestita, sp. nov. Fig. 15.

Bodies elongate-conical, soft, flexible and somewhat changeable in shape, less than three times as long as broad, tapering from the region beneath the peristome to the pedicle; cuticular surface, with the exception of the peristome border and ciliary disc, entirely clothed with a coarsely granular, mucilaginous investment; peristome exceeding the body-centre in width, the border slightly revolute; ciliary disc conspicuously exerted, and obliquely elevated; ciliary circles three; vestibular seta conspicuous; contractile vesicle single, spherical, anteriorly placed, apparently within the base of the ciliary disc; nucleus band-like, broad, short and curved; endoplasm granular; contracted body obovate, with several posteriorly developed annulations, and an anterior, snout-like projection; pedicle tree-like, profusely and dichotomously branching, longitudinally striate, becoming chestnut-brown with age; primary pedicle seldom exceeding in height twice the length of a single body, the ultimate branches about one-fifth as long as the zooids, often curved, a single animalcule being stationed on the extremity of each ultimate division. Length of body, $\frac{1}{100}$ inch; height of the entire foot-stalk, exclusive of the zooids, $\frac{1}{40}$ inch. *Hab.*—Pond water; attached to aquatic plants.

Thuricolopsis (*Thuricola*; *οψις*), gen. nov.

Animalcules loricate, the loricæ as in *Thuricola*, with the addition of an internal, narrow, flexible valve-rest, adherent to the lorica wall by one extremity, and projecting arcuately across the cavity to receive and support the descended valve; zooid posteriorly attached to the lorica by a distinctly developed pedicle; otherwise essentially as in *Thuricola*.

Thuricolopsis inniza. Fig. 16.

Thuricola inniza Stokes. Am. Monthly Micros. Journ., Oct., 1882.

Lorica subcylindrical, sessile, from four to five times as long as broad, somewhat attenuate posteriorly, the base of attachment truncate; the frontal border even, sometimes slightly everted; bearing internally, at some distance from the orifice, a valve-like appendage as in *Thuricola valvata*, and an opposite, rigidly attached but distally flexible membranous, setiform organ projecting arcuately inwards, and acting as a support to the descended valve, the wall of the lorica being inflated immediately behind this bristle-like valve-rest; enclosed animalcule pedicellate, projecting, when extended, one-third of its entire length beyond the lorica aperture. Length of lorica, $\frac{1}{150}$ inch. *Hab.*—Pond water; attached to various aquatic plants.

Thuricolopsis Kellicottiana, sp. nov. Fig. 17.

Lorica subcylindrical, sessile, less than four times as long as broad, the posterior region tapering, attenuate, subcylindrical and forming about one-eighth of the entire length; frontal border slightly everted; posterior extremity truncate; valve and bristle-like support essentially as in *Th. inniza*, the lorica wall not inflated behind the valve-rest; enclosed animalcule, when extended, long and attenuate, about one-fourth of its length projecting beyond the lorica aperture; pedicle filiform, from one-sixth to one-seventh as long as the lorica; cuticular surface smooth; two zooids frequently occupying the same sheath; nucleus extremely long, narrow and undulate; endoplasm granular; contracted body elongate obovate. Length of lorica, $\frac{1}{115}$ inch. *Hab.*—Pond water; attached to various aquatic plants.

This form was first observed by Prof. D. S. Kellicott attached to aquatic plants, at Corunna, Mich. (*Proc. Amer. Soc. Micros., 1884*), and by him referred to as a variety of *Th. inniza*. It occurs sparingly in the writer's locality in New Jersey, and seems sufficiently distinct to merit a specific title and place.

Platycola cœlochila, sp. nov. Fig. 18.

Lorica broadly ovate, becoming brown with age, less than three times as long as broad, dorsal surface convex; posterior extremity rounded, the anterior obliquely rounded or truncate, produced as a very short, vertical, neck-like prolongation, the margins slightly everted, the aperture transversely oval or subelliptical, laterally prolonged toward the ventral aspect, presenting, in lateral view, the appearance of a deep, rounded excavation; zooid, when extended, protruding for a considerable distance beyond the aperture; nucleus long, narrow, band-like. Length of lorica, $\frac{1}{215}$ inch. *Hab.*—Pond water; attached to the rootlets of *Lemna*.

Lagenophrys patina, sp. nov. Fig. 19.

Lorica nearly orbicular, much depressed, upper surface slightly convex, the lower plane; aperture circular, terminating a short, nearly perpendicular neck-like prolongation, surrounded by a thin, apparently membranous, horizontally projecting border, its margin irregularly and minutely crenulate. Diameter of lorica, $\frac{1}{450}$ to $\frac{1}{300}$ inch. *Hab.*—Pond water; attached to the legs and branchial appendages of *Gammarus*.

In form and size this closely resembles *L. ampulla* Stein, but differs in the absence of the everted and beaded rim projecting in front of the oral aperture in the first-mentioned species.

Histrio erethesticus, sp. nov. Fig. 20.

Body subelliptical, less than three times as long as broad, both extremities rounded, the lateral borders flattened, nearly parallel; lip semicircular; peristome-field reaching to the centre of the ventral surface, the right-hand margin bearing a membrane; frontal styles nine, the three anterior ones largest, the three posterior smallest, setose, inconspicuous; ventral styles five, more or less clustered, two on the right-hand side small, setose; anal styles large, stout, usually rigid, only the second and third on the right-hand side projecting beyond the posterior border; marginal setæ uninterrupted. Length of body, $\frac{1}{170}$ inch. *Hab.*—Shallow pools, with *Lemna* and Algæ.

The animalcule's movements during forward progression are constant but not especially rapid, nor long extended in one direction, but it has a most annoying habit of suddenly darting backward, for a distance seldom exceeding its own length, yet as it is impossible to anticipate the direction of this erratic movement, and as the change of position is extremely rapid, the eye fails to adjust itself soon enough to keep the creature distinctly visible. The Infusorian continues these backward leaps incessantly when not swimming forward, consequently it is a difficult animalcule to study. Occasionally, especially after long confinement, two contractile vesicles become apparent, a small vacuole developing near the centre of the left-hand margin of the peristome, in advance of the large normal vesicle.

Solenophrya odontophora, sp. nov. Fig. 21.

Lorica cup- or bowl-shaped, membranous, hyaline, the height about equal to the breadth, the posterior extremity rounded, the anterior border beneath the even, circular margin bearing from four to twelve attenuate, hollow, variously and inwardly curved, tooth-like processes; enclosed animalcule not adherent to the lorica; endoplasm finely granular. Height of the lorica including the processes, $\frac{1}{115}$ inch; length of the tooth-like processes, $\frac{1}{2250}$ inch. *Hab.*—Pond water; attached to Myriophyllum.

This form was first observed, and in considerable abundance, about four years ago, but has not since been met with. All the individuals then

noted had withdrawn the tentacles, and had become encysted within the lorica. The tentacles have therefore never been seen. These encysted forms were undergoing one stage of reproduction. The entire endoplasm is subdivided into very minute, remarkably active, biflagellate germs.

Acineta bifaria, sp. nov. Figs. 22, 23, 24.

Lorica, in side view, oval, the longest diameter less than twice the height; seen from above orbicular; the entire surface minutely tuberculate; pedicle very short, often only a small, inconspicuous, button-like projection; enclosed body attached to the posterior extremity only of the lorica, and divided into two unequal parts, the posterior region often entirely filling the cavity of the sheath, occasionally only about one-half filling it, the anterior portion subspherical, habitually extruded beyond the lorica aperture, and bearing the scattered capitate tentacles, the posterior or loricate portion often coarsely and longitudinally striate; endoplasm granular; contractile vesicles two, spherical, one situated near the lateral border of the anterior body-half, the other on the opposite side of the posterior or loricated region; nucleus apparently broadly ovate or subspherical, anteriorly placed; reproduction by transverse fission of the extruded anterior region, the embryo hypotrichous. Diameter of the lorica, $\frac{1}{250}$ inch. *Hab.*—An infusion of hay.

The first noticeable sign of approaching reproductive fission consists in an increased extrusion of the body substance, speedily followed by the formation of fine cilia on the anterior surface, with the appearance of a transverse constriction subcentrally situated on the extruded portion, as in Fig. 23. This constriction deepens, the cilia increase in length, soon entirely clothing the frontal region and one lateral margin, and, by the time the division is completed, the posterior border as well. At the final separation of the embryo it is ovate, coarsely granular, with a somewhat conspicuous nucleus. It speedily becomes elongated and flattened, as in Fig. 24, its length exceeding the height of the mature animalcule. The cilia are confined to the extremities and the lower surface, while a few short, capitate tentacles are scattered over the superior aspect. After the departure of the embryo the remaining portion of the mature animalcule withdraws itself into the lorica, as in Fig. 22, the anterior, subspherical region remaining exposed and the tentacles protruded. The latter become fewer in number, but are not entirely withdrawn during the reproductive act. After it they become more numerous.

The presence of the short, button-like pedicle of some individuals gives the lorica an appearance closely resembling that of *Solenophrya*, to which genus they might readily be relegated if not seen scattered among the more abundant and more distinctly pedicellate forms.

Acineta macrocaulis, sp. nov. Figs. 25, 26.

Lorica obovate or subspherical. Lorica obovate, the length only slightly exceeding the width, flexible, continuous, taking the form of the enclosed

zooid, the anterior border rounded, the lateral margins almost straight, tapering to the pedicle. Lorica subspherical, the anterior border slightly undulate, the anterior extremity of the pedicle suddenly expanded. Pedicle from seven to nine times as long as the lorica, hollow, its cavity continuous with that of the sheath; enclosed body usually entirely filling the lorica, soft, changeable in shape, not attached posteriorly to the lorica; endoplasm granular, enclosing numerous, large, refractive, probably amylaceous corpuscles; tentacles irregularly distributed at the anterior border, distinctly capitate, exhibiting spiral folds during their retraction; contractile vesicle apparently single, posteriorly placed near one lateral border; nucleus not observed. Length, including pedicle, $\frac{1}{100}$ to $\frac{1}{70}$ inch. *Hab.*—Pond water; attached to Myriophyllum.

Acineta acuminata, sp. nov. Fig. 27.

Lorica broadly vasiform, slightly longer than broad, the posterior border rounded, the anterior continuous, obliquely truncate on each side, and produced centrally in a prominent acumination, the lateral angles also often acuminately prolonged; the anterior borders on each side separated by a slit-like aperture, and the front wall bearing two narrow, anteriorly converging fissures, for the passage of the tentacles; pedicle hollow, from one-third to one-half as long as the lorica and communicating with its cavity; enclosed body subspherical, attached to the lorica anteriorly only and there taking the form of the sheath; tentacles fine, capitate, scarcely clustered; contractile vesicle single, spherical, situated near one side of the posterior extremity; nucleus large, subcentral; endoplasm granular. Length of lorica, $\frac{1}{300}$ inch; of pedicle, $\frac{1}{1500}$ to $\frac{1}{1125}$ inch. *Hab.*—Pond water.

The lateral angles are sometimes produced, sometimes rounded; and occasionally one will be rounded and the other slightly produced. The anterior central acumination has been present in all the forms observed. That only one wall of the lorica should be pierced by the two converging fissures is noteworthy. Corresponding lines on the opposite wall could not be perceived, although careful search was made for them.

Explanation of the Figures.

Fig. 1. Hexamita spiralis.
2. Petalomonas dorsalis. Diagram.
3. Urceolopsis sabulosa.
4. Trachelomonas urceolata.
5. Anisonema solenota.
6. Protoperidinium limbatum.
7. Holophrya ornata.
8. Saprophilus agitatus.
9. Bothrostoma undulans.
10. Hymenostoma magna.
11. Vorticella pusilla. Pedicle omitted.
12. Vorticella aqua-dulcis. Pedicle omitted.
13. Vorticella platysoma.
14. Opercularia allensi.
15. Opercularia vestita.

Fig. 16. Thuricolopsis innixa.
17. Thuricolopsis Kellicottiana.
18. Platycola cœlochila.
19. Lagenophrya patina.
20. Histrio erethesticus.
21. Solonophora odontophora.
22. Acineta bifaria.
23. A. bifaria. Reproductive fission.
24. A. bifaria. Embryo.
25, 26. Acineta macrocaulis. Pedicle omitted.
27. Acineta acuminata.

Preliminary Report on the Vertebrate Fossils of the Uinta Formation, collected by the Princeton Expedition of 1886. By W. B. Scott and Henry F. Osborn.

(*Read before the American Philosophical Society, Sept. 2, 1887.*)

The Uinta formation, which was first identified by Prof. Marsh, is one of great interest, as it is just intermediate between the Bridger and the White River groups. It has as yet been comparatively little explored, and much remains to be done, but enough is now known to render possible some account of this most important intermediate fauna.

REPTILIA.

Crocodilus, sp. indet.

Trionyx, sp. indet.

MAMMALIA.

Lemuroidea.

Hyopsodus gracilis Marsh.

Creodonta.

Mesonyx uintensis Scott.

Carnivora.

Amphicyon (?) *vulpinum*, sp. nov.—The probable existence of this genus in the Uinta beds is indicated by a lower premolar and lower sectorial molar. The premolar, probably the third, consists of a high, acute and compressed cone, with rudimentary posterior heel; a cingulum runs entirely around the crown, and is most conspicuous on the anterior surface. This tooth differs from the premolars of most of the European species of *Amphicyon* in the fact that the main cusp has no accessory tubercles developed upon it. The sectorial molar is canine in character; the blade consists of three cusps, of which the external is the larger, and the anterior is very low; the sectorial blade is therefore much less developed than in *Cynodictis*, and hardly more than in *Miacis*; the heel is low and small and not very distinctly basin-shaped. These teeth are insuffi-

cient for a final reference of the specimen, which may possibly belong to *Miacis*, but for stratigraphical reasons I think it more probably a species of *Amphicyon*. *Cynodictis* it certainly is not.

Measurements.

	M.
3d (?) lower premolar, antero-posterior diameter.....	.010
" " " transverse "	.004
1st lower molar, antero-posterior diameter.....	
" " " transverse "	

Another flesh-eater, exceeding the lion in size, is indicated by some metatarsals and phalanges. These may belong to the very large species of *Mesonyx* from the same beds, or to something quite different. No determination can be made at present.

Rodentia.

Plesiarctomys sciuroides, sp. nov.—Rodents have not as yet been announced from the Uinta deposits; representatives of two genera were, however, obtained by the Princeton party, one of which is the *Plesiarctomys* of the Wasatch and Bridger. In this species the molar formula is $\frac{5}{4}$; it differs from the other species of the genus which Cope defines as having the transverse crests of the upper molars "obsolete or wanting," in the structure of the upper molars, which are entirely like those of *Sciurus*, and consist of two external cusps, from which run two transverse crests, meeting internally and forming a V. The first upper premolar is very small and single-rooted. The lower molars are very like those of the Bridger species; there are four marginal tubercles surrounding a median depression; the antero-internal cusp is the highest; a low transverse crest connects the anterior pair of tubercles and a less distinct crest the posterior pair. These crests are better marked than in most species of *Plesiarctomys*. The skull has no post-orbital processes and a very large infra-orbital opening; the cranium is broad and flat, without sagittal crest, the inion low and rounded, the zygomatic arches much depressed and very thin, the cerebral hemispheres are entirely unconvoluted and leave the olfactory lobes and cerebellum exposed completely. This species is very small, less in size than *Plesiarctomys delicatissimus*.

Measurements.

	M.
Length of skull.....	.061
Breadth of skull, in front of orbits.....	.025
Length of lower jaw...	.028
Length upper molar series.....	.013
" lower " "	.012
Lower incisor, antero-posterior diameter.....	.003
" " transverse "	.002

A second species of rodent is represented by a lower incisor and part of the mandible, but as no molars are preserved, the specimen cannot be referred to any genus. The incisor is very much larger than in any known species of *Plesiarctomys*, and equals that of the beaver in size. It may not improbably belong to some ancestral member of the *Castoridæ*, as that family is known to exist in the overlying White River beds.

Measurements.

	M.
Antero-posterior diameter of lower incisor.....	.008
Transverse " " "	.0065

ARTIODACTYLA.

Protoreodon parvus, gen. et sp. nov. (?*Agriochoerus* Marsh).—This genus is of interest as being the direct forerunner of the *Oreodontidæ*, which are so characteristic of the American Miocene formations. It differs from *Oreodon* in the structure of the upper molars, which have five cusps, an intermediate one appearing between the anterior pair. The crowns of the upper molars are very wide and the internal crescents separated from the external by a considerable interval, much as in *Agriochoerus*. Both upper and lower premolars are somewhat simpler than in *Oreodon*, and the latter are trenchant, as in *Tragulus*. It differs very radically from *Agriochoerus* in the character of the premolars as well as in the presence of the intermediate cusp in the superior molars. The orbit is not enclosed behind, the cranium is narrower and less rounded and the brain smaller than in *Oreodon*. On the other hand, its relationship with that genus is incontestable; the lower teeth form a closed series without any diastemata, the lower canine has gone over to the incisor series, and the first premolar has taken on the form and function of the canine, a peculiarity found only among the *Oreodontidæ*. As in that family, the mandible is short, deep, and has an abruptly rounded chin.

The number of digits is uncertain, but is probably v–iv, as is unquestionably the case in *Oreodon;* the magnum has not moved so far to the radical side, but is more directly under the magnum than in the latter genus. In the tarsus the external and median cuneiforms are fused together as in *Oreodon*, but the line of union is much more plainly marked than in that genus.

Protoreodon parvus: Upper molar series, natural size. The inner cusp of the third premolar has been broken away.

This species was of very small size, much inferior to *Oreodon gracilis*.

PROC. AMER PHILOS. SOC. XXIV. 126. 2G. PRINTED NOV. 2, 1887.

Measurements.

	M.
Length upper molar series	? .053
" " premolar series	? .026
" " true molar "	.027
Length lower molar series	.054
" " premolar series	.027
" " true molar "	.027
Antero-posterior diameter, third upper molar	.010
Transverse " " " "	.008
Antero-posterior diameter, third lower molar	.012
Transverse " " " "	.006

Protoreodon (*?*) *pumilus* (*Agriochoerus pumilus*) Marsh.*—Professor Marsh has described a species of Agriochoerus from the Uinta beds, which more probably belongs to *Protoreodon;* but as the description given is very brief and no mention is made of the very characteristic antero-intermediate cusp on the upper molars, it may possibly be a member of some other genus.

Leptotragulus proavus, gen. et sp. nov.—This genus resembles the White River form *Leptomeryx*, but differs from it in the somewhat less complex structure of the last lower premolar, and in the presence of a strong accessory column between the external cusps of the lower molars. In all probability also this genus had separate metapodials, while in *Leptomeryx* there is a cannon-bone in the hind foot. Apparently the nearest ally of this genus is the *Prodremotherium* of Filhol, with which indeed it may prove to be identical; at present, however, we have judged it best to separate the American species, as aside from the fact that *Prodremotherium* has cannon-bones in both fore and hind feet, the last lower premolar, judging from Filhol's figures,† is somewhat more complex in structure, and less distinctly trenchant than in *Leptotragulus*. The latter is at once distinguished from its cotemporary *Protoreodon*, by the form of the mandible, which is very slender, with tapering chin and diastema behind the canine, while in *Protoreodon* the mandible is deep with abruptly rounded chin and no diastema; a further difference is found in the premolar formula of the lower jaw, four in *Protoreodon*, three in *Leptotragulus*. The premolars resemble most those of the tragulines; the last one consists of a high, sharp and compressed cone, with a very small antero-internal cusp, and a narrow valley on the posterior edge enclosed between two thin plates of enamel; this valley is not complicated by the accessory tubercles found in *Leptomeryx*.

The species *L. proavus* considerably exceeds in size the *Leptomeryx Evansi* of the White River formation, and is somewhat larger than *Tragulus javanicus*. The crowns of the lower molars are low and broad in proportion to their length.

* Am. Jour. Sci. and Arts, 3d Ser., Vol. ix, p. 250.

† Rech. sur les Phosphorites du Quercy, Figs. 265, 266.

The systematic position of this genus can hardly be decided from the material now at command; it may be a forerunner of *Leptomeryx*, the only genus of the White River formation which at all resembles it; it may be an ancestral type of the *Cervidæ*, or a member of the traguline series. These questions must for the present be left open.

Measurements.

	M.
Length lower premolar series	.021
Last lower premolar, antero-posterior diameter	.007
" " " transverse "	.003
First lower molar, antero-posterior diameter	.008
" " " transverse "	.005
Length lower true molar series (second specimen)	.026
Third lower molar, antero-posterior diameter (second specimen)	.012

Professor Marsh has named three genera of Uinta ruminants, *Eomeryx*, *Oromeryx* and *Parameryx**, with one of which *Leptotragulus* may be identical. As, however, no definition of these names has as yet been offered, they cannot be used.

PERISSODACTYLA.

Epihippus uintensis Marsh.†—This genus differs from the Bridger *Pliolophus* in having the last two inferior premolars of the molar pattern.

Epihippus gracilis Marsh.—Some beautifully preserved specimens of this small species are in the collection and show interesting differences from the Wasatch *Hyracotherium*. The characteristic equine cusps at the inner angle of the Vs on the lower molars are more isolated and distinct; the limb bones are proportionately longer and more slender; the carpus is higher and narrower; the magnum is more depressed and like that of *Anchitherium* in shape; there are still four digits in the manus, but No. V is very slender; the ulna is still further reduced. *Epihippus* forms a very interesting transition to the horses of the overlying White River deposits.

Hyrachyus obliquidens, sp. nov.—Specimens of this genus are not at all uncommon in the Uinta deposits, but the only ones which can as yet be satisfactorily determined belong to a species different from any of the known Bridger species. This species is characterized by the last upper molar, which has become exceedingly oblique and very like the corresponding tooth of *Aceratherium;* the antero-external lobe is greatly reduced in size, the external wall of the crown is nearly parallel to the posterior transverse crest and prolonged but little beyond it, so that the posterior valley is almost obsolete, being even less developed than in

* Introd. and Succ. of Vert. Life in America, pp. 29, 30.
† Loc. cit., p. 24.

Hyracodon. The rest of the dentition shows no particular deviation from the usual type, nor are important differences from the Bridger species observable in the skeleton, except perhaps a slight reduction in the relative size of the lateral digits. In size this species about equals *H. agrarius*.

Prothyracodon intermedium, gen. et sp. nov.—This very interesting type is apparently intermediate between *Hyrachyus* and *Hyracodon*. The type specimen consists of a fragment of the superior maxillary containing the fourth premolar and second molar in place, with the alveolus of the first molar. As in *Hyrachyus* the premolar has but a single internal cusp and two transverse crests enclosing a valley. The external cusps are like those of *Hyracodon*, the outer wall of the crown being nearly flat and subquadrate in outline; the two constituent cusps are but faintly indicated, but are somewhat more pronounced than in *Hyracodon*. An antero-external buttress or fold of the cingulum is present, as in both the Bridger and White River genera.

The second molar is essentially the same as in *Hyracodon*; the antero-external lobe is much more reduced than in *Hyrachyus*, and the transverse crests directed more obliquely inwards and backwards; but on the other hand, the projection from the anterior crest into the median valley which is to be seen on all the molars of *Hyracodon* is here wanting.

The present species is quite small; it is about the size of *Hyrachyus agrarius*.

Measurements.

	M.
Fourth upper premolar, antero-posterior diameter.....	.010
" " " transverse "	.014
Second upper molar, antero-posterior diameter.....	.016
" " " transverse "	.0175

Isectolophus annectens, gen et sp. nov.—This genus is closely allied to *Helaletes* of the Bridger, but its dentition is one step nearer to that of the tapir. In *Helaletes* the antero-external cusp of the upper molars is less reduced and there is less difference between that and the postero-external cusp, than in *Hyrachyus*. This tooth structure would almost suffice to remove *Helaletes* from the *Lophiodontidæ* as defined by Cope. In *Isectolophus* this equality of the external cusps is still better marked, and, more important still, the external wall is extended behind the posterior pillar just as in the tapir, so that this pillar becomes a median thickening of the postero-external cusp, instead of being a thickening of the posterior edge of that cusp, as in *Hyrachyus* and *Helaletes*. The first and second upper molars are thus almost exactly like those of the tapir; the transverse crests are low and thick, and a strong cingulum surrounds the crown. The premolars are probably all simpler than the molars; at all events this is true of the third. The lower molars are like those of *Helaletes*, and the last one has a well-developed heel or third crest; there seems, how-

ever, to have been a diastema between the canine and first premolar, though this is not certain, which is not the case in *Helaletes*.

The species is rather small, somewhat larger than *Helaletes latidens* of the Bridger.

Measurements.

	M.
Length upper molar series	.048
First molar, antero-posterior diameter (?)	.015
" " transverse " (?)	.015
Second " antero-posterior "	.015
" " transverse "	.014
Third " antero-posterior "	.016
" " transverse "	.018
Third upper premolar, antero posterior diameter	.012
" " " transverse "	....
Third lower molar, antero-posterior "	.023
" " " transverse "	.011

The study of this genus shows that *Hyrachyus* and *Desmatotherium* cannot be placed in the direct line of tapir ancestry, as we were formerly disposed to believe. Much more probably this line has come down through the genera with trilobed last lower molar, and it is noteworthy that the tapiroids from the White River beds have the third lobe or talon present, though less distinctly marked. These animals have been described by Dr. Leidy,* under the name of *Lophiodon*, from which genus the known specimens do not appreciably differ. But, as Dr. Leidy has suggested, they probably belong to a very different genus, which, when better known, will in all likelihood be found to be intermediate in character between *Isectolophus* of the Uinta and *Tapiravus* of the Loup Fork. According to this view the series of genera would be: *Helaletes*, *Isectolophus*, the White River genus, *Tapiravus* and *Tapirus*.

Amynodon Marsh (*Syn. ? Orthocynodon*, nobis).—Professor Marsh's description of this genus is as follows:† "The skull is intermediate in form between that of a Tapir and a Rhinoceros, but the molar teeth are entirely of the latter type. The premolars are all unlike the molars, and the canines above and below are very large. The incisors are small and the inner one in each jaw is lost in the present adult animal. The lower canines are placed nearly horizontal, and, taken in connection with the rest of the anterior dentition, they prove conclusively that the large lower teeth usually regarded as incisors in *Aceratherium* * * * are really canines." The number of digits is stated to be iv–iii. This description is erroneous in most of the particulars, owing to the fact that it was drawn up before the type specimen had been removed from the matrix and put together, and in this way, even after examining the type ourselves, as

* Ext. Mamm. Faun. of Dak. and Neb., p. 239.

† Am. Journ. Sci. and Arts, Third Ser., Vol. xiv, p. 251.

Professor Marsh kindly allowed us to do, we were formerly led to consider the Bridger species as a distinct genus* (*Orthocynodon*).

The numerous specimens from the Uinta formation now in the Princeton collection show that *Orthocynodon* is very probably identical with *Amynodon*. The premolars are not all unlike the molars, as the third and fourth of the upper premolar series have all the molar elements, but are somewhat smaller; the incisors are present in their full number in the upper jaw; the lower canines are not procumbent but fully erect. We can therefore confirm Professor Marsh's statements only with regard to the pattern of the molar teeth and probably also as to the number of digits.

Amynodon advenus Marsh is the only species as yet known from the Uinta beds, in which, especially in the higher strata, it is very abundant.

Diplacodon elatus Marsh.†—This animal, the largest yet known from the Uinta, is of especial interest as being intermediate between the Chalitherioids of the Bridger (*Palæosyops*, *Leurocephalus*, etc.), and the gigantic *Menodontidæ* of the White River, as was first suggested by Professor Marsh. The dentition is like that of *Palæosyops*, but the premolars have commenced to assume the molar pattern; there are, however, no traces of the horn-like processes so characteristic of *Menodus*. The skeleton, which is very fully represented in the collection, is massive, and in many respects closely like that of *Menodus*. The cervical vertebræ are short, with opisthocœlous centra and quite long spines; the dorsal vertebræ are heavy and in the anterior region have very long spines, which, however, do not reach the extreme length found in *Menodus;* the lumbars are rhinocerotic in character; the ribs are long, flattened and heavy. The scapula is, like that of *Menodus*, very rhinocerotic, long and narrow, but with more abruptly rising spine and rudimentary metacromion; the humerus is very massive, with strongly developed deltoid hook and supinator ridge; this humerus is a somewhat reduced copy of that of *Menodus;* the ulna is stout for its entire length and has a very prominent olecranon; the radius differs in no essential except size from that of *Menodus;* the carpus is low and broad, the metacarpals and phalanges like those of *Palæosyops*, only stouter. The pelvis is like that of *Palæosyops*, with long, pedunculate and plate-like ilium, which is not everted nearly so much as in *Menodus*, and long, heavy and trihedral ischium; the femur is long and massive, with very prominent third trochanter, and with the rotular trochlea narrower and deeper than in *Menodus;* the tibia is shorter than the femur; the calcaneum has a very long tuber calcis and a narrow cuboidal facet, considerably narrower than in *Palæosyops;* it appears also to possess the distinct fibular facet which is found in *Menodus;* the astragalus is broader and shallower than in *Palæosyops*, and has a more exten-

* Bull. E. M. Museum, No. 3, pp. 1 *et seq.*

† Am. Journ. Sci. and Arts, 3d Ser., Vol. ix, p. 246. Introd. and Succ. Vert. Life, p. 27.

sive bearing upon the cuboid, while it is narrower than in *Menodus*, and has a less extensive contact with the cuboid. The number of digits is apparently iv–iii.

The characters revealed by this skeleton abundantly confirm Professor Marsh's view that *Diplacodon* is to be regarded as the ancestor of *Menodus*, and as a descendant of the Bridger Chalicotherioids.

The Uinta fauna differs in many very important respects from that of the Bridger formation, both in what it possesses and in what it lacks; nevertheless it is on the whole more closely akin to the Bridger than to the White River fauna. The great *Dinocerata* seem to have completely disappeared, as have also the *Tillodonta;* rodents, lemuroids, and creodonts are very much less common than in the Bridger, and what seem to be the first true American carnivores have appeared; perissodactyls of chalicotherioid, lophiodont, equine and rhinocerotic types are still very numerous. But the most remarkable and striking change consists in the extraordinary increase in the number of selenodont artiodactyls, which are exceedingly rare in the Bridger, but in the Uinta are perhaps more abundantly represented, as far as individuals are concerned, than any other group of mammals; in character these artiodactyls are distinctly like those of the White River epoch. As yet no bunodont artiodactyls have been discovered, though they doubtless existed. With the possible exception of *Agriochoerus* (see p. 257), no genus is yet known which is common to the White River and Uinta formations, while several Bridger genera are represented in the latter; there are *Plesiarctomys*, *Mesonyx*, *Hyrachyus*, *Amynodon*, and perhaps others. No perissodactyl in which the premolars have all taken on the molar pattern, and no artiodactyl with coalesced metapodials, is known in this fauna, which thus has a distinctly older facies than the fauna of Quercy,* which, however, agrees with it in the great increase in selenodonts. Schlosser† considers the Uinta fauna as Oligocene, but, as we believe, without good reason, since not a single Miocene genus has been found in it, the genera being all either common to the Bridger or peculiar to the Uinta. The term oligocene is much more properly applied to the overlying White River beds, as has been done by Messrs. Cope and Filhol.‡ It seems, therefore, best on the whole to regard the Uinta as forming the summit of the eocene, as Professor Marsh, who first described its fauna, has done.

Synopsis of the Uinta Fauna.

	Genera.	Species.
Rodentia	2	2
Lemuroidea	1	1
Creodonta	1	1

* Filhol Phosph. du Quercy, pp. 517–554.

† Morph. Jahrb., Bd. xii, p.

‡ Bibl. de l'École d. Hautes Études; Sect. d. Sci. Nat. T., xix, p. 21 (separatim).

	Genera.	Species.
Carnivora (?)	1	1
Artiodactyla	2	3
Perissodactyla	6	7
	13	15

For the very extensive and valuable collections of Uinta fossils now preserved in the Princeton museum, of which a brief account has been given above, we are chiefly indebted to the energy and skill of Mr. Francis Speir, Jr., of New York, who was in charge of the expedition of 1886.

GEOLOGICAL MUSEUM, PRINCETON, N. J., July 12, 1887.

On the Systematic Position of the Mallophaga. By A. S. Packard.

(*Read before the American Philosophical Society, September 2, 1887.*)

The true position of the bird-lice has been in debate for many years, and it is only recently that, in the excellent essay of Grosse,* we have such an exact account of the mouth-parts of these insects, as to enable us to perceive that they have been wrongly referred to the Hemiptera. With the new information afforded by Grosse, who does not himself add any general conclusions as to the systematic position of the Mallophaga, beyond stating that they are not Hemiptera, nor allied to the true lice, we have for our own satisfaction made some comparisons with the Psocidæ, to which, among winged insects, the parasites in question seem nearest allied.

The name *Mallophaga* was first proposed by Nitzsch in Germar's "Mag. der Entomologie," iii, 270, 1812.† In Gerstaecker's "Arthropoden" of Peters and Carus' "Handbuch der Zoologie" (1863), where this group is placed with the lice among the Hemiptera, it is stated that Burmeister regarded the Mallophaga as Orthoptera: "Zwischen welchen und den Hemipteren sie in Anbetracht ihrer Verwandtschaft mit den Läusen ein Uebergangsglied abgeben, ohne füglich einer von beiden Ordnungen direct zugewiesen werden zu können."

In our "Guide to the Study of Insects" (1868), and in subsequent editions, influenced by general usage and also by Melnikow's arguments, based on embryological studies, we placed the Mallophaga among the Hemiptera, next to the true lice. In most, if not all German, Dutch, and French, as well as English text-books, the Mallophaga, if referred to, are described with the true lice. But, in his article, "Insects," in the "Encyclo-

* Beitrage zur Kenntniss der Mallophagen. Von Dr. Franz Grosse. Zeits. für wissen. Zool., xlii, 1885, pp. 530-558. A lengthy illustrated abstract by Prof. G. McCloskey will be found in the American Naturalist, April, 1886, pp. 340-348.

† I am indebted to Dr. Hagen for this reference to Nitzsch's paper.

pædia Britannica," 9th edit., Mr. R. McLachlan claimed that these insects should be regarded as degraded Pseudoneuroptera. This view seems a natural one. Struck by this suggestion, and before reading Nitzsch's essay on the internal anatomy of Atropos, we had been led into comparisons with the Psocidæ, particularly the wingless form Atropos, to which, as we hope to show, with the aid of Grosse's results, the bird-lice are more closely allied than to any other group of insects. Grosse himself, unfortunately does not intimate what his views are as to the exact systematic position of the group under consideration, beyond affirming that they certainly are not Hemiptera.

We will now turn to the conclusions of Melnikow,* derived from a study of the embryology both of the Mallophaga and the true lice. In this essay the author thus sums up his views as to the affinities of the Mallophaga:

"The study of the embryology of the Pediculidæ and Mallophaga affords proof of a complete similarity in the mode of development of these two groups of animals. We are convinced that the similarity urged is seen not only in the identity of the formation of the primitive streak and the relations of the embryonal membranes, but also in other more subordinate features of the development. We have for example perceived that in the lice as well as the Mallophaga a provisional mass of cells is formed before the completion of the blastoderm; that both have the provisional membrane which the larva leaves behind it in the egg at the time of hatching. Finally we are in a position to state that the beaks of both groups of insects are independently formed of the appendages of the head-segments.

"These, though subordinate processes of development, appear to us to be of more value in the comparison of the insects under consideration than the relations of the mode of formation of the primitive streak and of the embryonal membranes, since the last without doubt is generally common to those insects with an internal primitive streak, but the former must be regarded as the distinctive feature of the insects under consideration.

"If we add to the results mentioned, the fact that the anatomical structure of the mouth-parts in the insects of the two groups agrees in all essential points; if we add the generally similar external form of these insects, finally their ectoparasitic mode of life, then we need not hesitate to recognize the close relationship of the lice and Mallophaga.

"This conviction is not insignificant, since it affords us the possibility of decisively answering the question as to the systematic position of these insects.

"After the researches of Burmeister it was generally considered that the Pediculidæ belonged to the Hemiptera. The structure of their mouth-parts and the incomplete metamorphosis they undergo are the reasons which confirm such a view.

* Beiträge zur embryonal Entwickelung der Insekten. Archiv f. Natur-Gesch., xxxv 1869.

"But the Mallophaga were regarded by De Geer as a special group, and by Nitzsch and others they were generally referred to the Orthoptera. So far as I am aware, only Gerstaecker, in his "Handbuch der Zoologie," places the Mallophaga at the end of the Hemiptera; still he is inclined to consider the group as a special one, forming a sort of transition from the Hemiptera to the Orthoptera, but without forming a direct connecting link.

"Since until now, we knew only of the biting mouth-parts of the Mallophaga, so the view that they were entitled to be regarded as Orthoptera was completely founded. In the Orthoptera we place those insects with an incomplete metamorphosis and biting mouth-parts. But after the existence of a beak in the Mallophaga has been proved, it becomes evident that they should be regarded as Hemiptera or bugs.

"This conclusion is wholly indisputable when we recall the above-mentioned similarity of the Mallophaga with the genuine lice. As to the completeness of this similarity, I will call attention again to the relations of the mouth-parts, which have been cleared up by our embryological studies. We are thereby brought to the conviction that in the lice as well as in the Mallophaga, in their adult condition, no underlip (labium) exists, while the mandibles and maxillæ are present. The only difference in the mouth-parts of the two groups is this: that in the Mallophaga these head-appendages are the functional parts of the mouth-apparatus, while in the Pediculidæ they become rudimentary.

"But such relative differences do not have so great systematic value as to lead us to place so nearly related animals in two different orders.

"From the reasons we have presented we adopt the Linnean view that the Mallophaga belong with the Pediculidæ; we think we are right in regarding both groups as families of the Rhynchota."

From the foregoing facts and conclusions of Melnikow, we felt convinced that he had demonstrated that the Mallophaga were Hemiptera and nearly related to the Pediculidæ. But after a careful reading of Grosse's memoir on the Mallophaga, translated by Prof. McCloskey, we think he is right in considering that these biting lice are not genuine Hemiptera. The very fact, admitted by Melnikow, that the mandibles and maxillæ retain their biting function and do not become rudimentary as in the Pediculidæ, and the fact pointed out by Grosse, that the second maxillæ do exist in the Mallophaga, leads us to regard their louse-like shape as simply adaptive, and that they belong to some other group than the Hemiptera.

If we examine Melnikow's excellent figures we see that after the mouth-parts of the embryo of both the genuine Pediculidæ and Mallophaga are developed, the embryos of the two groups follow different developmental paths. The large clypeal region of the Mallophaga becomes still larger and broader, overhanging and concealing from above the labrum, which is short and broad; on the other hand, in the Pediculus it becomes long, narrow and slender. The mandibles become true biting jaws, while in the Pediculus they become long and slender; the maxillæ become minute

and short, of the masticatory type in the Mallophaga, while in the Pediculus they remain large and long (Melnikow, Fig. 371) and of the size and shape of the mandibles; the second maxillæ in Pediculus are, in this stage, as large as in the first maxillæ, while in the Mallophaga they become minute. After the stage indicated by Melnikow's Fig. 37 (Pediculus) and Figs. 32, 33 and 34 (*Trichodectes canis*) the ordinal differences become more marked.

Among the Pseudoneuroptera of Erichson, a group which is so unnatural that it will have to be abandoned, we have after the elimination of the Odonata and the Plectoptera or Ephemeridæ, the families of Perlidæ, Psocidæ, Embidæ, and Termitidæ, which we have associated together in the order *Platyptera*. It is to the wingless Psocidæ that the Mallophaga appear to bear the closest resemblance. If we compare certain Mallophaga, especially those with a small prothorax, such as Goniocotes, Docophorus, etc., with the wingless Atropos, or the wingless young of Psocus, there is a general similarity to the latter in the small thorax, the large oval abdomen and the large head, with the small eyes. But these resemblances are superficial. But, however, with the aid of Grosse's figures of the mouth-parts of the Mallophaga and Mr. E. Burgess' excellent figures of the mouth-parts of the Psocidæ*, three of which we reproduce, we find an unexpected homology, which shows that the Mallophaga are, so to speak, degraded Psocidæ.

One characteristic of the Mallophaga, in general, is the greatly enlarged front or clypeal region of the head, which is vaulted and conceals from above the mouth-parts, and sometimes even the antennæ, with the occasional exception of the labial palpi. In the bird-lice, the lower, rounded edge of this circular clypeal region is applied to the surface on which the animal rests, as seen in Figs. 1 and 5, the labium and mouth-parts not being seen from above, except in some genera where the maxillary palpi project laterally.

In the Psocidæ the position of the head is vertical, as seen in Fig. 10, and the labrum is not covered by the clypeus; but the Mallophaga are unlike these and other insects in having the labrum covered by the clypeus.

In the shape of the mandibles the Mallophaga closely resemble the Psocidæ, at least as much so as perhaps any other of the biting insects.

Mr. Burgess has figured and described the first maxillæ of Psocus (Figs. 10 and 11) and Atropos (Fig. 12). The cardo and stipes are rudimentary; the latter bearing besides the four-jointed palpus a thick fleshy lobe homologous with the galea or outer maxillary lobe of other biting, ametabolous insects. He also describes at length the peculiar "fork," which has no homologue in the Mallophaga any more than other insects, Mr. Burgess inclining to the view that this is an independent organ. It is to be noticed that, with the exception of the palpi, the maxillæ of the Psocidæ are much atrophied.

* The Anatomy of the Head, and the Structure of the Maxilla in the Psocidæ. By Edward Burgess. Proc. Boston Soc. Nat. Hist., xix, 291-296, 1878.

In the Mallophaga they are excessively so, there being, if we accept Grosse's statement, apparently no palpi, and the maxilla being reduced to a pair of minute conical appendages, divided into two segments. After careful examination, Grosse says that he has never been able to find the palpi of the first maxillæ which Nitzsch ascribed to the Liotheidæ.*

The labium or second maxillæ of the Liotheidæ, as described and figured by Grosse (Fig. 8), consists of two parts united by a transverse fold. To the mentum are attached the four-jointed labial palpi. In front of the mentum is the ligula or glossa (*g*). In all Liotheidæ, the interna of the ventral end of the oral cavity forms a fold-like duplicature, forming the hypopharynx, Fig. 2 *hy*. In Læmobothrium and Tetrophthalmus this extends forward over the labium, and its lateral borders are strongly bent upwards (Figs. 1, 8 *hy*).

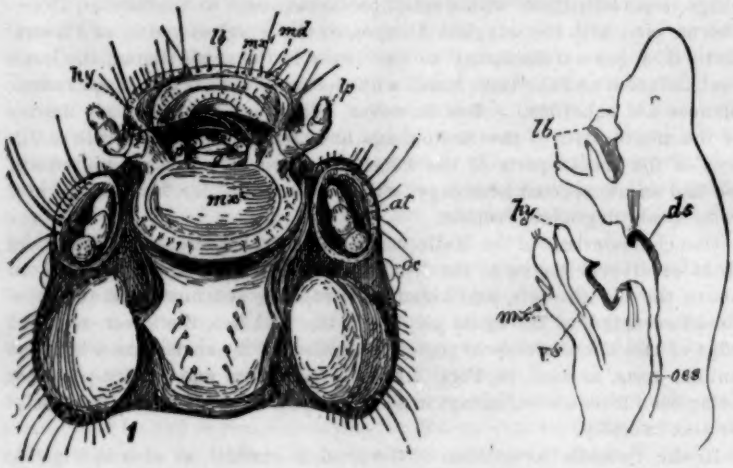


Fig. 1.—Under side of head of Læmobothrium. × 30.
Fig. 2.—Median section through head of *Goniodes dissimilis*. × 60.

The two-jointed organs on the sides of the tongue or ligula are called paraglossæ by Grosse (Figs. 7, 8, 9 *p*). In Nirmus and other Philopteridæ there are no labial palpi, the paraglossæ persisting (Fig. 7).

If we now compare the mouth-parts of the Mallophaga with those of the Platyptera we shall find a more or less close homology. In the first place the ligula appears as in the latter forms (Termes and Perlidæ), to be divided, as in Liotheidæ, into four lobes, while the outer pair of lobes, the paraglossæ, are usua ly, if not always, present, even when the labial

* Nitzsch figures them in *Trinotum conspurcatum*, but this can scarcely be correct, for he places the four-jointed papillæ on the blade near its anterior border. In Tetrophthalmus the palps belong, not to the first, but to the second maxillæ. The same is true of *Menopon pallidum*, *Colpocephalum zebra*, a Læmobothrium and a Trinotum, and probably is the case with all the genera and species. McCloskey's Transl.

FIG. 3.—Labrum of *Gonodes dissimilis*. × 60.

FIG. 4.—Right and left mandibles of Tetrophthalmus. × 60. FIG. 5.—Head of *Lipeurus heterographus*, seen from below. × 60. FIG. 6.—First maxillæ of Tetrophthalmus. × 75.

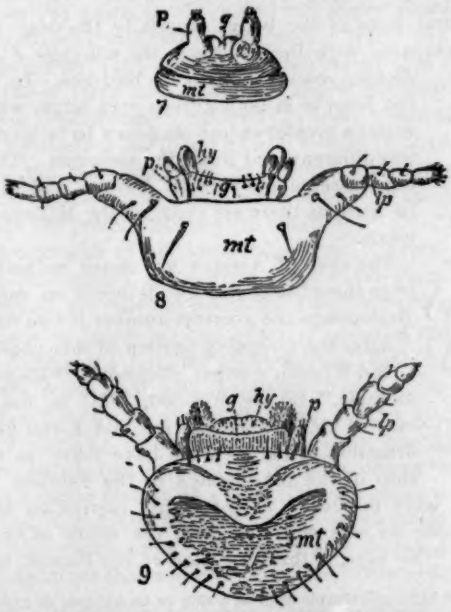
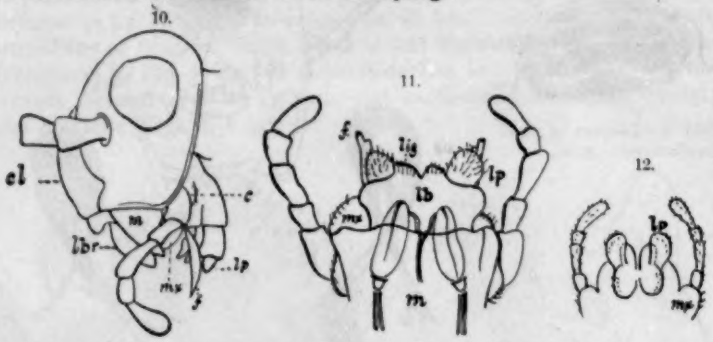


FIG. 7.—Second maxillæ of Nirmus. × 60. FIG. 8.—Second maxillæ of *Tetrophthalmus hilensis*. × 60. FIG. 9.—Second maxillæ of Læmobothrium. × 60.

palpi are atrophied. But while the second maxillæ of the Termitidæ and Perlidæ are well developed, the degraded condition of those of the Psocidæ affords a passage, though not a direct one to be sure (the labial palpi in Psocus and Atropos being simply one-jointed and there being no paraglossæ), to the Mallophaga. We copy, however, the accompanying sketches from Mr. Burgess' paper, so that the reader may compare the mouth-parts of the Psocidæ with those of the Mallophaga.



FIGS. 10, 11.—Psocus. 10, side view of the head; *cl*, clypeus; *lbr*, labrum; *m*, mandible; *mx*, maxilla; *f*, fork; *c*, cardo; 11, *m*, mentum; *lp*, labial palpus; *lig*, ligula.
FIG. 12.—Atropos, labium. *lp*, palpus; *mx*, maxilla.—After Burgess.

In the general form of the body, especially the shape of the thoracic segments as compared with the abdomen, the wingless Atropos shows a decided resemblance to the bird-lice. In the first place, the head is in both groups very large, while the thorax shows a greater or less tendency to be merged into, or be less differentiated from, the abdomen. The latter region has ten segments both in Atropos and the Mallophaga. In Atropos there are three, in the Mallophaga two tarsal joints.

FIG. 13.—*Atropos pulsatorius*. Author del.

The eyes of Atropos are much reduced, there being from three* to seven simple ocelli on each side; in the Mallophaga the greatest number is two on each side.

After the foregoing portion of this paper was written, I read Nitzsch's paper (Germar's "Magazin der Entomologie," Bd. iv, 276–290, 1821) on the internal anatomy of *Atropos pulsatorius*, and found unexpected confirmation of the view we have taken as to the relationship of the Mallophaga to the Psocidæ. His observations, he says, were the result of researches carried on about the year 1814, at the time he was occupied with the study of the Mallophaga. "I undertook," he says, "the dissection of the Psocus, because this in-

* Scudder found but three simple eyes on a side in an Atropos he examined. Psyche. ii, 51.

sect has some external similarity with those parasites, and because I entertained the idea, that the internal structure of the same might offer some points which would be of value in throwing light on the natural affinity of the insect parasites, at least of the biting species." The following comparisons are taken from Nitzsch's memoir :—

"The digestive canal of *A. pulsatorius* differs from that of the Mallophaga only in the crop and the constantly present upper flap or diverticulum of the stomach. There are four simple, unbranched Malphigian tubes both in *A. pulsatorius* and in the Mallophaga. Of ovarian tubes there are five pairs in *A. pulsatorius*, and in Mallophaga from three (*Liotheidæ*) to five pairs (*Philopteridæ*)." After describing the ovaries and oviduct, he goes on to say: "Herein appears an unexpected similarity between the Psocidæ and the animal insect parasites, for the entire structure of their uterus and the number of their ovarian tubes, also the shape of the egg itself, is like that which had already been described by Swammerdam in the louse, and by myself in the genera Philopterus and Trichodectes. In Liotheum and Gyropus, however, the number of ovarian tubes is somewhat smaller."

In the nature of their food and their manner of taking it there is a close resemblance between the Psocidæ and Mallophaga.

As is well known, the Psocidæ occur on the trunks of trees, fences, old walls, etc., and feed on decaying vegetable matter. "Atropos, as is well known, lives on the paste in old books and boxes, as well as the specimens of entomological cabinets" (Burgess). While the food-habits of the Mallophaga are not fully known, Nitzsch stated that they eat the epidermal products of birds and mammals, and sometimes blood. Grosse found that blood is rarely taken, and only in cases where the hosts (birds) are so injured or diseased as to have blood among their plumage. Leuckart arrived at the same result as to *Trichodectes canis* of the dog. In Læmobothrium, Grosse found the intestine filled with the limbs of its own kind, as if it ate the product of its own moulting.

From the present state of our knowledge then, it seems reasonable to infer that the Mallophaga are nearest allied to the Psocidæ, and are degraded members of the order to which the Psocidæ belong.

It now remains to determine the exact relations of the Mallophaga to the order containing the families of Termitidæ, Embidæ, Psocidæ, etc., and here we are confronted with the difficulty of limiting the order containing these families, which were with other groups placed in the order of Pseudoneuroptera by Erichson. In my essay on "The Systematic Position of the Orthoptera in relation to other orders of Insects,"* I retained, though under protest, this order; at the same time stating, "It is difficult, if not impossible, to satisfactorily characterize by a sharp-cut definition this very elastic order. As regards the thorax, there is no uniformity in the structure that we have been able to discover, nor is there in

* Third Report U. S. Entomological Commission, 1883, pp. 286-345.

the structure of the wings, nor more than a general resemblance in the mouth-parts." I provisionally divided the group into three suborders :—

1. *Platyptera.* Termitidæ, Embidæ, Psocidæ, and Perlidæ (= Corrodentia and Orthoptera amphibiotica in part).

2. *Odonata* (Libellulidæ).

3. *Ephemerina* (Ephemeridæ).

I also added, "It is comparatively easy to give well-grounded differential characters for these three suborders. They are so distinct that they may, perhaps, hereafter be regarded as entitled to the rank of orders, or the Pseudoneuroptera may be dismembered into the Pseudoneuroptera and Subulicornia (Odonata and Ephemerina)."

Without giving the wing characters and after describing on p. 291 the second maxillæ, the Platyptera are defined on p. 292, and the structure of the thorax and abdomen described in some detail on pp. 322–329 (in the latter pages the group is referred to as Corrodentia).

Afterwards, in his Systematisch-Zoologische Studien* (1885), Dr. Brauer boldly divides all the winged insects, the Synaptera (Thysanura) excepted, into sixteen orders. He regards the Perlidæ as the type of a distinct order (*Plecoptera*), while his order *Corrodentia* embraces the Termitidæ, Psocidæ and Mallophaga (the Embidæ are referred to the genuine Orthoptera).

In his description of the Corrodentia, Dr. Brauer frequently refers to the Mallophaga, especially referring to the similarity between the thorax of the Atropina and Mallophaga.

As will be remembered, Burmeister's order *Corrodentia* included the families Termitidæ, Embidæ, and Psocidæ. Under these circumstances the name Corrodentia should be restricted to a subdivision of the order Platyptera.

In 1886, in the fifth edition of our text-book on Zoölogy,† we added the Mallophaga to the Platyptera, which thus included the groups of Mallophaga, Perlidæ, Psocidæ, Embidæ, and Termitidæ. Although Dr. Brauer (following Burmeister who proposed the order Plecoptera for the Perlidæ) separates the Perlidæ from the Corrodentia as restricted by him for the reason that the former (Perlidæ) have numerous Malphigian tubes, are hemimetabolous and perennibranchiate, we are not yet prepared from a study of the trunk characters and of the shape of the second maxillæ, as well as the wings and their mode of folding, to separate the Perlidæ from the other Platyptera.

But once within the limits of the order, it is evident that the Mallophaga, even if degraded Platyptera, should occupy a space distinctly separate from the winged members of the group; in fine, they should be referred to a distinct suborder, equivalent to all the winged forms taken together. Hence the Platyptera may be divided into two suborders :—

I. Mallophaga.

II. Platyptera genuina : Superfamily 1, Plecoptera (Perlidæ) ; Superfamily 2, Corrodentia.

* Aus dem XCI. Bande der Sitzb. der Kais. Akad. der Wissensch. I. Abth., Mai-Heft. Jahrjang 1885.

† See also American Naturalist, Sept., 1886, p. 808.

On the Reptiles and Batrachians of Grand Cayman. By Samuel Garman, Cambridge, Mass.

(*Read before the American Philosophical Society, October 7, 1887.*)

Grand Cayman island is situated in the Caribbean sea, south of Cuba—in round numbers—about two hundred miles, west north-west of Jamaica about the same distance, and not far from four hundred miles east of Yucatan. It is a comparatively recent coral formation and rises but little above the sea. In total length it approaches twenty-five miles, but in width it is less than three.

Consideration of the origin, size and position of Grand Cayman, together with the directions of its currents, winds and traffic, prepares us for the conclusion, reached from study of a portion of its terrestrial fauna, that it has received its land animals, not so very long ago, from the neighboring large islands.

The collection on which this notice is based, purchased by the Museum of Comparative Zoölogy, from Mr. W. B. Richardson, contained one hundred and five specimens, representing in all six species: three lizards, one snake, one toad and one treefrog. One of the lizards, a little Anolis, is nearly related to a species from Jamaica; another, a Gecco, belongs to a Jamaican species, and is hardly distinct enough to rank as a variety; and the third forms a species nearest to one described by Professor Cope from Navassa (eastward from Jamaica) and close to another from Cuba. The snake and the treefrog belong to Cuban species. And the toad ranges from Jamaica to Brazil. There might be more hesitation in calling one of the forms distinct if it were not for its complete isolation. It is because of this, and, also, because of the likelihood that the differences are becoming greater and more numerous with time, that the details of description are so much dwelt upon. Besides, the closeness of the affinities, with forms belonging to the other islands, makes it the more necessary to deal with particulars.

The list includes the following:

Anolis conspersus, sp. n.

Liocephalus varius, sp. n.

Aristelliger præsignis Hallow.; Cope.

Alsophis caymanus, var. n.

Bufo marinus Linn.; Schneid.

Hyla septentrionalis Tschudi.; Blgr.

ANOLIS CONSPERSUS, sp. n.

Head large, about one and three-fourths times as long as broad, longer than the tibia. Forehead concave. Frontal ridges low. Occiput concave. Scales on the sides and top of the head with low blunt keels.

Scales of the supraorbital semicircles enlarged, separated mesially by a single series of scales. Ten to fifteen enlarged keeled supraocular scales, the largest of which is separated from the supraorbitals by a single series of granules. Occipital small, about the size of the ear-opening, separated from the supraorbitals by three or four series of scales. Canthus rostralis sharp, prominent; canthal scales four. Loreal rows five. Six labials to below the centre of the eye. Ear-opening small, vertical diameter much the greater. Gular appendage rather large, the fold reaching as far backward as the axil, less developed in the female. Gular scales flat, with faint indication of an obtuse keel. Body not compressed; a slight nuchal fold in the male; no dorsal fold. Dorsal scales small, granular, smooth or obtusely keeled, a little larger in several of the vertebral rows; ventral scales larger. Limbs moderate; the adpressed hind leg reaches the orbit; digital expansions moderate; lamellæ under phalanges ii and iii of the fourth toe twenty-four. Tail twice as long as head and body, compressed, less in female, edged above with a series of strongly keeled scales. Male with enlarged postanal scales.

Adults yellowish-green to olivaceous, thickly sprinkled with small spots of light color, reddish or brownish in life; tail more uniform; belly bluish, presenting a clouded appearance toward flanks and chin. Goitre blue or purple.

Very young ones are light ashy or grayish on the back, white beneath; somewhat clouded with darker on flanks, limbs, chin and throat. The light spots or freckles first appear on the top and sides of the head, thence gradually spreading backward. Above the pelvis on the back there is a band of light color which narrowing backward extends to the middle of the tail, where it fades. On one specimen there is a small dark blotch at each side of the pelvic band; on the middle of the body there is a small transverse hour-glass-shaped blotch with a smaller rounded spot of white at each side of it on the mesial line; it has a similar mark above the axils, and a dark spot on the occipital shield. On many individuals, old and young, the forehead and cheeks are brown.

This species is closely allied to *A. grahami* as accepted by Dr. Boulenger, whose form of description we have followed, more or less nearly, to facilitate comparisons. *A. conspersus* has a much smaller occipital scale, its canthal and frontal ridges are sharper, it has a single series between the supraorbitals on the crown; it has not the lilac color on tail and limbs, and its goitre is dark blue or purple, instead of crimson with yellow or white margin.

Liocephalus varius, sp. n.

Upper head-scales large, smooth or faintly striate; nasal in contact with the rostral; supraorbitals in contact on the median line; supraoculars six to eight, the majority of which are separated from the supraorbitals by a single series of small scales. Parietals two pairs in one row, the outer of each pair being nearly twice the size of the inner; the inner

elongate, narrow, twice as long as broad, separated on the mesial line by the interparietal and, in cases, by a small scale behind it. In front of the interparietal there is a pair of small shields, and in front of them one or more small ones. The number of plates between the supraoculars and interparietal varies from three to five. Two pairs of the supraorbitals are in contact across the forehead behind the frontal. Three cross-rows of plates behind the internasals. Frontal medium, hexangular. A pair of larger prefrontals, in front of which there is a second pair of smaller ones, the two pairs being sometimes separated at their inner angles by a small lozenge-shaped plate. Internasals elongate, narrow, with the acute posterior extremity directed obliquely outward. Auricular scales two to three, broad, upper largest. Scales in front of ear moderately large, smooth. On the sides of the neck the skin is strongly folded, covered with keeled small scales. Dorsal crest low. Dorsal scales mucronate, the keels obliquely turned toward the vertebral line. The scales of the flank are smaller and rather abruptly turned upward. The ventrals are about as large as the dorsals, smooth, broader than long, and rounded on posterior margin. There are forty-one to forty-three rows of scales, counting around the middle of the body. The adpressed hind limb does not reach the eye. Tail feebly compressed, more than one and one-half times as long as the body, with a crest a little stronger than that of the back.

Olive brown, with a metallic lustre, clouded with dark brown, which in earlier stages was apparently arranged in transverse bands. Faint indications of a light band on the upper edge of each flank. Olivaceous beneath, lighter backward and sprinkled or clouded with many small spots of white. Tail ringed with brown, about seventeen rings. Chin and throat clouded or reticulated with olive and white. A light band from the hinder angle of the eye to the angle of the mouth. Lighter scales sprinkled over the body and limbs, both above and beneath.

This species is allied to *L. eremitus* Cope from Navassa, and with it to *L. carinatus* of Cuba and the Bahamas, more than to the others. The distinguishing characters appear in the scales of the head, in the relative sizes of those of the body, and in the coloration.

ARISTELLIGER PRÆSIGNIS Hallowell; Cope.

Total length of the largest specimen six and a half inches; snout to vent two and a half.

Half-grown examples are grayish-brown to brownish-gray, white beneath. The top of the head is nearly uniform brown. From each nostril through the eye to the shoulder there is a lighter edged brown band; these bands converge in approaching the shoulders. From the shoulders backward there are brownish darker edged blotches, each of which presents an angle toward the vertebræ, thus enclosing lozenge-shaped lighter spots on the median line. On the sides of the tail these lateral blotches alternate, or, meeting, form transverse bands of brown. Labials brown, with or without whitish spots. Chin mottled with brownish. The color

is darker on the largest specimen; the light spots of the back continue beyond the base of the tail; but anteriorly the ground color has become so dark that the spots and bands are obscured.

Hallowell's specimens, from Jamaica, were "uniform brown above with no lines or spots." The circular pupil and the clawless thumb were probably oversights. Such measurements as he gives would make his types smaller than the largest described above. Dr. Boulenger's description, also taken from Jamaican specimens, answers much better to those from Grand Cayman.

ALSOPHIS CAYMANUS.

A. angulifer Bibr.; Cope, var. n.

Body moderate, blunt-angled at the edge of the abdomen; head distinct, narrowed in front, subquadrangular in transverse section, flattened on the crown; tail nearly one-third of the total length, slender. Eye moderate. Teeth small, longer and farther apart backward. Scales with two pores, smooth, in seventeen rows; dorsal longer than broad, outer and caudal as broad as long. Ventrals broad; in five specimens they number 167, 170, 171, 173, and 175 respectively. Anal bifid. Subcaudals in two series; in three specimens there are 125, 127, and 129 pairs. Crown-shields nine; internasals moderate, narrower forward; prefrontals broader than long, bent downward, and shortened, at the loreal; frontal about twice as long as broad, truncate in front, narrower and having parallel sides behind the middle, acute-angled between the parietals; supraoculars large, broad posteriorly; parietals very large, outer anterior angle in contact with the lower postorbital. Rostral medium, hardly reaching the top of the snout, in contact with six plates. Nostril between the quadrate halves of the small nasal. Loreal small, quadrangular, hinder lower angle acute. One anteorbital, reaching the top of the head, not in contact with the frontal. Two postorbitals; lower in contact with the fifth and sixth labials and the temporal; upper meeting the supraocular and the parietal. Temporal large, narrow anteriorly, bounded by the lower postorbital, the posterior three labials, and two post-temporals. Of the latter the upper is the larger. Labials eight, third, fourth and fifth in orbit, sixth and seventh very large. Lower labials ten, first pair meeting behind the mental, first six in contact with the submentals, fifth and sixth largest. Mental small triangular. Submentals two pairs, posterior much longer, each of the anterior meeting five, and each of the posterior meeting two of the lower labials.

Large specimens have a ground color of reddish brown, and the greater number of the scales black-edged or black-tipped; backward they have irregular spots of dark including one to several scales; and the belly appears to have been a brick-red in life. The larger ones have transverse blotches of brown under the tail, and numerous white-edged scales similar to those of *Liophis cobella*. Some have vertical bands or blotches of brown anteriorly on the flanks; farther back these meet on the vertebral line and become transverse bands.

Very young ones are ashy or grayish, with brown puncticulations; the head and posterior margins of ventrals and subcaudals are darker; a white-edged brown band passes from the nostrils, spreading to include the eye, to the eighth labial; and chin, throat and lips are mottled with brownish.

Half-grown are less uniform, and more brown; they have scattered white-bordered scales in the anterior half of the length, faint indications of transverse dorsal bands of brown, and an indefinitely margined brown band across the head from the hinder edges of the orbits.

BUFO MARINUS Linn.; Schneid.

A single quite young individual appears in the collection. Compared with many others of the same size from Jamaica, it is rather more smooth and of lighter color. The Jamaican examples are roughened with sharp points and in general color are dark brown; the spots on the ventral surface are numerous and dark. On the Cayman specimen the color is ashy or grayish, and the spots beneath have a faded olivaceous tint. Spots, glands and warts have similar positions and shapes in both cases.

Nothing can be said of the place whence this species came, it is so generally distributed among the West Indies, from Jamaica southward, and along the coasts of South and Central America.

HYLA SEPTENTRIONALIS Tschudi; Blgr.

In very large specimens the habit is massive and much like that of the toad; the skin is glandular, and, in some, covered with large smooth warts. On young ones the skin is quite smooth. A male, less than one-fourth the size of the females, has a blackish rugosity on the inner side of the first finger.

The color varies from grayish olive to brown, irregularly marked with darker on the back. Ventral surface whitish, with or without spots or cloudings of dark anteriorly. Limbs with transverse bands of brown. In the folds in front of the shoulder the brown takes the form of narrow vertical lines. Behind the thighs and along the flanks there are irregular small spots or reticulations of brown. On small ones there is a white band on the posterior half of the upper lip, a brown one behind each eye through the tympanum toward the shoulder, and a transverse band, concave forward, across the head between the eyes.

No differences are noted between these and others from Cuba.

Mr. Richardson states that the natives reported a crocodile in the swamps. This might be expected from the presence of two species on Cuba, one of which appears also on Jamaica and San Domingo. In completing the list of the Grand Cayman reptiles it will, no doubt, be necessary to add the names of the marine turtles, *Thalassochelys cephalo*, *Chelonia mydas*, *Eretmochelys imbricata*, and *Dermatochelys coriacea*.

On West Indian Reptiles in the Museum of Comparative Zoölogy, at Cambridge, Mass. By Samuel Garman.

(*Read before the American Philosophical Society, October 7, 1887.*)

The following list includes the snakes, turtles and crocodiles of the collection. A large proportion of them was collected by the writer, on opportunities provided by Prof. Alex. Agassiz; the remainder was secured by purchase from different collectors. Among the species there are a number not previously recognized; the ranges of others have been extended by the localities represented in the series.

In the snakes it is found necessary to place more than the usual stress on variation of the number of rows of scales, or of the number of scutes in the ventral and subcaudal series, since the representatives of a single species on one or another of the small islands may be distinguished by a couple of dorsal rows more or less, or by a few scutes more or less on the lower surface; variations that would have comparatively little value on the mainland, but which here derive importance from their fixity, a consequence of isolation. *Alsophis cinereus*, as compared with *A. rufiventris*, furnishes a good illustration.

Typhlops richardi D. & B.

A specimen from St. Kitts island has twenty rows of scales, in 321 + 13 transverse series. In squamation it differs little from the species as described from St. Thomas.

Stenostoma albifrons Wagl.

One taken at Trinidad has its scales in fourteen rows, in 194 + 19 transverse series. It disagrees with others from Pará in having two broad shields cross the back immediately behind the first three of the median series, which are of the average size.

Boa constrictor Linné.

Trinidad.

Boa diviniloquax Laur.; Dum. & Bibr.

On a couple of these boas from Dominica the transverse series number sixty-five in each case.

Ungualia melanura Schleg.; Gray.

Cuba. Scales in twenty-seven rows, the outer five of each side smooth; transverse series 214 + 41.

Ungualia maculata Bibr.; Gray.

Cuba. According to Bibron this form has twenty-five rows of scales, in 200 + 35 to 40 transverse series.

UNGUALIA HAETIANA Cope.

Hayti. Scales in twenty-seven rows; ventral scutes 193 + 38. Loreals and anterior pair of prefrontals fused.

UNGUALIA CURTA, nom. sp. n.

U. maculata Cope, not of Bibron. Cuba. Scales in twenty-five rows; ventrals 154 + 27. Loreals fused with the anterior prefrontals. Prof. Cope's specimens gave the species twenty-three to twenty-five rows, and 142 to 150 ventrals. The markings of this snake are somewhat like those of *U. maculata*. In the dorsal series the blotches have white lateral margins.

XIPHOSOMA HORTULANUM L.; Fitz.

Trinidad, Grenada, St. Vincent, Petit Martinique, Grenadines. The total length of the largest is six feet three inches, of which the tail is thirteen. Excessive variations in color are shown by these examples; one from Trinidad is light yellowish olive clouded with brown, with edges of scales brown, and ventrals yellow blotched with darker. The markings are obsolete on others not nearly so large. One from Grenada has the marks very distinct, black with light borders; a second is similar as regards their shapes but the spots are faint; and a third is nearly uniform brownish, with yellow ventral surface, and an indistinct trace of a blotch here and there. A St. Vincent type is very dark; the blotches are large, black, and continued down the flank as rather broad vertical bars; the top of the head is vermiculated with brown. That from Petit Martinique is very distinctly marked; the ground color is grayish and the blotches are black, with white margins. One from the Grenadines is of the average, another is a uniform dingy yellow, as if the brown pigment had entirely disappeared, leaving no traces of the markings. Dorsal rows 39–43; ventrals 256–285, subcaudals 107–117.

EPICRATES CENCHRIA L.; Wagl.

Trinidad. One of these has a single labial in contact with the eye on each side; on the left it is the sixth and on the right the seventh. Another has the sixth and seventh in the orbit on one side and the seventh and eighth on the other. The markings are very indistinct.

HOMALOCHILUS STRIATUS Fisch.

Hayti.

HOMALOCHILUS STRIGILATUS Cope.

Andros island, Bahamas.

CHILABOTHRUS INORNATUS Reinh.; D. & B.

Bayamon, Porto Rico. This species is very common along the streams on the branches of the trees. It is easily taken by means of a stick bearing a noose of strong twine.

Rhabdosoma lineatum.

Dumeril & Bibron, 1854, Erp. Gen., vii, 105, describe this species from Java. There is no doubt that the specimens described below came from Trinidad; they were taken by the writer near Port of Spain. Prof. Jan has already questioned the locality given by Dum. & Bibr., most likely with reason. Prof. Cope tells me he also has noted the species from Trinidad. The individual variations are so great that we may yet have to include Jan's *R. punctivittatum*.

Body stout, cylindrical; head not distinct from neck, subconical, slightly depressed; tail short, thick, pointed. Eye small, pupil round. Crown-shields nine; internasals small, short; prefrontals large, long, narrow in front, broad behind, entering the orbit; frontal subtriangular, as broad as long, acute-angled between the parietals; supraoculars small, broad; parietals large, wide; nasals divided, nostril in the anterior half, both anterior angles acute. Loreal widest in front, long; entering the orbit in one specimen, not fused with the anteorbital in another. Postorbitals two; temporals 1 + 2, upper elongate. Labials eight, first small, eighth large, fourth and fifth in orbit. Lower labials eight, fourth and fifth largest; submentals one pair, large, in contact each side with first four lower labials, separated from the small mental by the first pair. Scales smooth, broad, in fifteen rows. Anal entire. Ventrals 146, 136; subcaudals thirteen pairs in one, eighteen in the other. Total length 8.5, tail 0.5 inches.

Color light reddish brown, puncticulate with brown. A median narrow streak of brown from the occiput, another on the upper edge of the third and lower edge of the fourth, and another on the upper edge of the first and lower edge of the second rows. Belly white (? red or yellowish in life). Head darker, clouded. On one specimen the edges of the scales are darker.

Liophis cobella L.; Wagl.

Trinidad. Rows 17; ventrals 157; anal bifid; subcaudal 62 pairs.

Dromicus dumerilii.

Calamaria dumerilii Blbr.

Urotheca dumerilii Bibr.

Rows 17; ventrals 153; anal bifid. The specimen agrees well with the description except in the number of ventrals, which was 128, twenty-five less than in the present.

Dromicus cursor LaC.

Martinique. Scales in seventeen rows, with one pore. Ventrals 194, 191, 191, 186, 185. Anal bifid. Subcaudals 106, 103, 101 pairs.

The name *cursor* was given to this species by LaCépède in 1789, Quad. Ovip. et Serp., ii, pp. 96, 280, Pl. xiv, f. 2. Donndorff from this figure and description renamed it *fugitivus* in 1798, Zool. Beytr., iii, 206.

DROMICUS CURSOR, var. PLEII.

Dromicus pleii D. & B.

Martinique, in the low-lands near Fort de France. Rows 17; ventrals 195, 193, 192, 190; anal bifid; subcaudals 107, 104, 101 pairs.

These specimens are much lighter-colored than those from the heights; the colors are more olivaceous, and the bands are as in the original description.

DROMICUS CUBENSIS, nom. sp. n.

Cuba. This is the *D. cursor* of Bibron, but not of LaCépède. Rows 17; ventrals 149, 145, 145, 142, 140; anal bifid; subcaudals 87, 92, 94, 106 pairs. Near the base of the tail some of the scales bear two pores; farther forward but one may be discovered, and anteriorly they become obsolete.

DROMICUS JULIÆ Cope, sp.

Dominica. Rows 17; one pore; ventrals 157, 161, 162; anal bifid; subcaudals 77, 84 pairs.

On a variety of this species found in Marie Galante the marks are not so black as on those from Dominica. Instead of a bright yellow spot near the middle of the scale, the lighter portion is more olive and the coloring is more irregularly placed. Ventrals 161, 164; subcaudals 82, 81 pairs.

DROMICUS ORNATUS, sp. n.

St. Lucia. Rows 17; one pore; ventrals 190, four 191 each, 194; anal bifid; subcaudals 86, 85, 88, 86, 91 pairs.

This handsome serpent is much like the Couresse of Martinique. Its tail appears to be a trifle shorter; its colors distinguish it very readily. From neck to end of tail it has a median band of brown, which on the body is about six scales wide and which contains two rows of round or squarish spots of white larger than a single scale and separated from each other by spaces of like width. On the third row there is a dark stripe in which the scales are marked with a yellow spot. The anterior edges of the ventrals are black. A black band behind the eye; a yellow spot on the lateral edge of each parietal; two or three transverse yellow streaks on the snout. Ground color of labials and lower surface yellowish or white. *D. cursor* has a white vitta at each side of a black band of five or six scales in width; anteriorly the vitta is more or less broken into spots but the included band lacks the two series of spots.

DROMICUS TEMPORALIS Cope.

This appears to be the species figured by Jan and Sordelli under the name of *D. nuntius*. The specimen which served as type of *D. temporalis* has the locality Cuba. It has seventeen rows; pores not visible; ventrals 166; anal bifid; loreal and anteorbital fused on both sides.

DROMICUS PARVIFRONS Cope.

Hayti. Jeremie, Hayti. Rows 19; no pores; ventrals 142 on each of three specimens, 143; subcaudals 113, 118, 113, 119 pairs.

DROMICUS MELANOTUS Shaw, sp.

Trinidad; Grenada. Rows 17; one pore; ventrals 147, 149, 153, 149; anal bifid; subcaudals 59, 62, 59, 65 pairs.

The dorsal black band is five whole and two half scales in width; the white line at each side of it is two half scales wide, as also the black line on the flank; the yellow or pinkish of the abdomen extends over three and a half of the outer rows. Anteriorly the lateral black lines are broken into spots and in the black vertebral band there are small whitish spots.

DROMICUS EXIGUUS Cope.

St. Thomas. Rows 19; ventrals 139, 140; anal bifid; subcaudals 80, 83 pairs. One has the prefrontals fused on the median line.

ALSOPHIS ATER Gosse; Cope.

Kingston, Jamaica. Rows 17; pores 2; ventrals 171, 180, 185; anal bifid; subcaudals 162, 149, 144 pairs.

ALSOPHIS ANTILLENSIS Schleg.; Fitz.

St. Thomas; Hayti. Eight specimens at hand have nineteen rows each; 172 to 181 ventrals; and the subcaudals range from 134 to 142 pairs.

ALSOPHIS ANGULIFER Bibr., sp.

Cuba; Havana, Cuba. Rows 17; ventrals 164, 167, 169, 167; subcaudals 102, 114, 108, 108 pairs.

ALSOPHIS CAYMANUS Garm.

Grand Cayman. A variety of the preceding.

ALSOPHIS RUFIVENTRIS D. & B.

St. Kitts; Saba; Nevis. On each of twenty-two specimens the number of rows is twenty three; the ventrals range from 208 to 220, and the subcaudals 114 to 122. On nine the tail is mutilated. Apparently there is a special cause for the prevalence of the mutilation in particular localities.

ALSOPHIS CINEREUS Garm.

St. Barts; Anguilla. Six from St. Barts have the scales in twenty-one rows; the ventrals ranging from 203 to 207, and the subcaudals from 115 to 122. They are darker than the following. Six from Anguilla have twenty-one rows each; ventrals 201 to 203, and the subcaudals 99 to 115. These are more ashy in color than those from St. Barts, which are darker than

the allied species from St. Kitts, Saba and Nevis. They form a variety of the preceding.

Alsophis sibonius Cope.

Dominica. Rows 19; pores two; ventrals 198.

This specimen disagrees in several particulars from the original description. The agreements, however, are so exact, when occurring, that the variations are most likely to prove individual. The temporals are 1–1–2–3, the anterior on each side being divided vertically in such manner as to leave a short piece in contact with the orbitals; the seventh labial is large; each parietal has five or six scales in contact with its outer border. In color it is almost black. A black band waves from side to side on the back, its concavities being marked by triangular spots of white. A series of black spots on the middle of the flank, much fused; a series of smaller ones on the outer edges of the ventrals and on the first row of scales. Forward the ventral surface is yellow with black specks; behind the middle the white disappears on back and belly in a uniform black.

Alsophis melanichnus Cope.

Bayamon, Porto Rico. Rows 17; pores two; ventrals 169, 170; subcaudals 125, 129; loreal pentagonal; lower postorbital very narrow, about one-third as large as the upper; temporals 1–2–3. The narrowness of the lower postorbital is a good distinguishing character. On young specimens the dark-bordered scales are distributed in such way as to form irregular transverse bands, more indistinct in larger ones.

Alsophis pulcher, sp. n.

Testigos island. Rows 17; two pores; ventrals 190; anal bifid. Head distinct, broad behind; body slightly compressed; tail mutilated. Labials nine, fourth, fifth and sixth in the orbit, eighth largest; lower labials eleven, sixth largest. Loreal low, upper edge horizontal. One anteorbital; two postorbitals. Snout rounded, rostral, internasals, and prefrontals convex. Prefrontals bent down to meet the loreal. Loreal region concave. Temporals irregular 2–2–2. Frontal broad and truncate anteriorly, narrow and rounded behind.

Brownish-yellow, darker in front, with a median black edged band of yellowish-brown on the back, five scales and two halves in width. At each side of this there is a yellow band, one scale and two half scales in width, margined by a dark streak. On the flank the yellow band is margined by a dark streak occupying half of each of the second and third rows. Each ventral is marked on its outer-anterior edge by a black spot, which forms a zigzag line along the edge of the abdomen. Belly yellow; chin and throat blotched with dark brown. A dark streak from the nostril through the eye. Toward the neck the amount of black on the scales is much greater and the dorsal band appears as if composed of three.

IALTRIS VULTUOSUS Cope.

Jeremie, Hayti; types. Rows 19; two pores; ventrals 182–188; anal bifid; subcaudals 105, may be a little shortened.

HYPSIRHYNCHUS SCALARIS Cope.

Jeremie, Hayti; type. Rows 19; one pore; ventrals 166; anal bifid.

HERPETODRYAS CARINATUS L.; Boie.

Kingston, St. Vincent. Two specimens. Rows 12, outer smooth; ventrals 173, 164; anal bifid; subcaudals 162, 153 pairs.

HERPETODRYAS BODDÆRTII Seetz.; Schleg.

Kingston, St. Vincent; Trinidad. Rows 17; pores two; ventrals 191, 193, 202, 204, 200, 194, 196, 204; subcaudals 118, 105, 110, 118, 122, 124, 127, 118 pairs.

UROMACER OXYRHYNCHUS Dum. & Bibr.

Hayti. Rows 19; ventrals 200; anal bifid. The bluish-green of the back shades gradually into the light color of the belly; there are no puncticulations; the white line on the flank is narrow, obsolete on the anterior third of the length, distinct on the remainder of the body and the base of the tail. The snout is less sharp than in the variety.

Var. A. Samana, San Domingo.

Rows 19; ventrals 192; anal bifid; subcaudals 199 pairs. Snout acute. Color grass-green; white band on the outer row occupies nearly the whole scale, is very distinct and extends over half the length of the tail; abdomen gray, puncticulate with brown, and with a few scattered small spots of black.

UROMACER INORNATUS, sp. n.

Jeremie, Hayti. Four examples. Rows 17; ventrals 182, 184, 188, 190; anal bifid; subcaudals 201 on the only entire. Snout more blunt than *U. oxyrhynchus*. Color nearly the same on back and belly; bluish-green puncticulate with brown.

UROMACER CATESBYI Schleg.; D. & B.

Jeremie, Hayti. Rows 17; ventrals 163 in three and 165 in the fourth; anal bifid; subcaudals 181 pairs in one, 206 in another.

DRYIOPHIS ÆNEUS Wagl.; Cuv.

One specimen of five from Trinidad has fifteen rows of scales; the others have seventeen. Ventrals 192, 187, 177; subcaudals 177, 164, 162 pairs. One from Testigos islands has nine labials, the fifth and sixth in the orbit; it has seventeen rows, and 181 ventrals.

LEPTODEIRA ANNULATA L.; Fitz.

Trinidad. Rows 19; ventrals 178; subcaudals 90 pairs.

DIPSAS CENCHOA L.; Wied.

Trinidad. Rows 17; ventrals 247, 233, 247; subcaudals 158, 160, 165 pairs.

SCYTALE CORONATUM Schneid.; D. & B.

Grenada. Ventrals 195, 188, 186; subcaudals 73, 86, 85.

OXYRHOPUS PLUMBEUS Wagl.; Gthr.

Grenada. Rows 19; ventrals 233.
St. Lucia. Rows 17; ventrals 233, 232; subcaudals 71 pairs.

ELAPS RIISII Jan.

Trinidad. Ventrals 184, 186, 184; subcaudals 3 + 42 pairs, 17 + 25 pairs, 45 pairs; bands 30 + 9, 25 + 11, 25 + 10. Two postorbitals.

ELAPS LEMNISCATUS L.; Schneid.

Trinidad. Ventrals 221; subcaudals 36 pairs; bands 36, eleven groups of three.

TRIGONOCEPHALUS LANCEOLATUS Oppel.

Martinique. Rows 31, 32, 33; ventrals 217, 220, 223; subcaudals 53, 68, 59 pairs.

TRIGONOCEPHALUS CARIBBÆUS, sp. n.

St. Lucia. Labials 7 to 8; lower labials 8 to 11. Rows of scales 25, 27, 27; ventrals 197, 206, 209; subcaudals 64, 69 pairs. This serpent is more slender than that from Martinique; it has narrower scales and not nearly so many of them. In color the tendency is toward olive, more or less uniform; the brown blotches being almost obsolete in cases. Belly whitish to yellowish, with few or no puncticulations. Individuals vary from light olive with white belly to dark olive-brown with yellowish ventrals.

The Martinique serpent is brown rather than olive; the brown blotches are more distinct, and the puncticulations on dorsals and outer portions of ventrals are abundant; the bellies are yellow. Individuals vary from yellow to black.

This is the *Craspedocephalus atrox* of Lieut. Tyler, 1849. Pr. Zoöl. Soc. Lond., 100, but is not that species, as found on the mainland, to which the name was originally given by Linné, Laurenti, Gray, Fitzinger and others.

TESTUDINATA.

Testudo tabulata Walbaum.

Abundant in the market at Port of Spain, Trinidad. Secured also at St. Vincent and St. Lucia. It feeds readily in captivity and is kept about the houses and carried from place to place much as the more common domestic animals.

Emys rugosa Shaw; Gray.

From the markets at San Juan, Porto Rico, and from Cuba.

Cinosternum sp.

A small turtle, sent by Prof. Felipe Poey, of Havana, possesses characters that separate it from both of the species, *C. pennsylvanicum* and *C. leucostomum*, which it approaches most nearly.

It is elongate; the snout is narrower and more pointed than that of the first-mentioned species. The greatest length of the carapace is exactly four, its greatest width two and three-fourths, behind the middle, the greatest length of the plastron three and nine-tenths, and the width of the plastron across the pectoral shields is one and nine-tenths inches. Anteriorly the plastron is rounded; posteriorly it is truncate, with a shallow notch between the anal shields. The pair of pectoral shields, like the pair of preanals, meet on the median line in a suture of about three-eighths of an inch. A single pair of barbels close together under the lower jaw.

Color light yellowish-olive with darker margins to the shields. Head sprinkled with light spots. A narrow streak of light color passes around the snout on the rostral angle above the eye and along the side of the head to the neck.

Chelonia mydas L.; Schweigger.

At certain feeding grounds among the leeward islands a great many of these turtles are taken for shipment to various ports. In the same resorts "Loggerheads," "Shell turtles," and "Trunkbacks" are said to occur.

CROCODILIA.

Crocodilus rhombifer Cuv.

From Cuba.

Crocodilus americanus Schneid.

The collections contain specimens from Jamaica, Hayti and Cuba.

Memoir of Pliny Earle Chase. By Philip C. Garrett.

(*Read before the American Philosophical Society, October 21, 1887.*)

Pliny Early Chase was a native of the old Puritan Commonwealth which has probably contributed more than any other to the intellectual life of this country. He was born at Worcester, Mass., on the 18th of August, 1820, and was descended on both sides from the hardy and intelligent yeomanry of New England, most of his ancestors in this country having been farmers. His father, Anthony Chase, was for thirty-four years Treasurer of the county of Worcester and for thirty years President of the Worcester Mutual Fire Insurance Co., and died as recently as 1879 at the advanced age of eighty-eight years. His mother was Lydia Earle, of the neighboring town of Leicester. Her father, Pliny Earle, "made the first cards ever propelled by mechanical power in America, and invented a machine by which the manufacture of them was greatly facilitated;" Dr. Pliny Earle, one of the most distinguished alienists of this country, was her brother; another was Thomas Earle, an eminent philanthropist, member of the Pennsylvania Constitutional Convention of 1837 and candidate of the Liberal Party for the Vice-Presidency in 1840; a third, John Milton Earle, was for many years Editor of the Massachusetts "Spy."

The subject of this Memoir was of the eighth generation in descent from Ralph Earle, who "was on the island of Rhode Island in 1638, was one of the petitioners to the King for permission for the formation of a 'body politic' on that island, and was subsequently a member of their legislative Assembly."

Pliny Earle Chase's early education was received at the Worcester Latin School, the principal of which, at that time, Hon. Charles Thurber, afterwards member of the Massachusetts Senate, preceded his distinguished pupil to the "Silent Land" only a few days. Ex-President John Adams had been a teacher in the same school. Pliny afterwards attended the Friends' School at Providence, R. I., and entered Harvard in 1835, graduating from that University in 1839 with the degree of A. B., and receiving that of A. M. in 1844. "As a boy, he was bright, intelligent, apt and quick in the acquisition of knowledge, but without special precocity. He was always one of the best scholars, but there was nothing that indicated the profundity of intellect manifested in his later years." In a letter to his uncle, he writes, in his Freshman year: "I am chiefly guided in the path which I intend to pursue by an aspiration after such honors as are calculated to be of lasting benefit in forming an acquaintance with the ways of the world and in acquiring *honorable fame.*"

He was then only fifteen years of age, but his career would indicate that he kept this honorable ambition of his boyhood constantly in view throughout life. Edward Everett Hale, who was a Harvard classmate, informs that he was "distinguished for scholarship, especially for mathematical scholar-

ship, in his class at Cambridge. He was one of a special advanced section in mathematics, of which no member had had to take a lesson a second time. They were therefore so much in advance of the great body of the class that, at the end of the mathematical course, they had the advantage of special instruction from Prof. Peirce in higher mathematics. He was interested in all branches of physics. I remember him especially," writes Mr. Hale, "as one of eight observers who made some of the first observations which are on record of the shooting stars. The record will be found in the 'American Journal of Science,' of 1837, and I believe of the 'Comptes Rendus' of the French Academy of the same year. He was a quiet, unobtrusive young man, but a favorite with the class from his uniform courtesy, and a rare sense of humor, which never left him through life." Upon taking his degree at Harvard, he immediately entered the pedagogic profession, at first in district schools in Leicester and Worcester, then in 1840–1 as Associate Teacher in the Boarding-school at Providence, in which he himself had prepared for College. In 1841–2 he taught at Friends' Select School on Cherry street, in Philadelphia, and, from 1842 to 1844, conducted a private school in the latter city. On the 28th of June, 1843, he married Elizabeth Brown Oliver, of Lynn, whose brother, Prof. James E. Oliver, of Cornell University, was a man of kindred tastes to his own. The following two years were spent in New England, where he prepared for publication his first book, the "Elements of Arithmetic, Parts I and II," afterwards published by Uriah Hunt & Sons, of Philadelphia. This was followed, in 1848, by "The Common School Arithmetic." In the course of 1850, in connection with Horace Mann, he prepared and published "Mann & Chase's Arithmetic, practically applied," remodeling the 1st and 2nd parts of the "Elements of Arithmetic" into a new series, which was published by E. H. Butler & Co., Philadelphia.

Dr. Thomas Hill, ex-President of Harvard University, bears the following testimony to the value of his arithmetical works: "Chase's Arithmetic was the best I ever saw. The two books 'Chase' and 'Chase & Mann,' as we called them, were worth all other arithmetics that I ever saw put together. When I first introduced 'Chase' into the public schools of Waltham, I had a hard battle with the committee and with the teachers. They thought it too difficult, etc., but, in less than one year, all were satisfied, and at the end of three years, all enthusiastic. No schools in Massachusetts, and I believe none in the world, equaled our Waltham schools in arithmetic. But the publishers sold the plates to a Boston firm, who had another and inferior book to push, and they melted up the plates of Chase, to my intense indignation." Stronger proof of their merit could scarcely be given. Dr. Hill regarded them not as compilations, such as the common run of arithmetics, but as original contributions to pedagogy, and "classed Mr. Chase not with mere compilers, but rather with the originators, whose work is more akin to Pestalozzi's, and who deserve to rank very high;" and probably no higher testimony could be produced than Dr. Hill's, on this point.

In the fall of 1845, Mr. Chase returned to Philadelphia and conducted a private school for girls, at the same time giving lessons in other schools and in families. In all probability, he would have continued uninterruptedly in the pursuit of that profession, in which he was beginning to earn a measure of the "honorable fame" to which he aspired in his boyhood, had not severe hæmorrhages of the lungs, occurring three years later and continuing, with diminishing frequency, for ten years, compelled him to relinquish teaching. His physicians recommended a life which would allow of more out-door air and exercise, and he entered into a manufacturing business, under the name of North, Harrison & Co.

Two years later, John Edgar Thomson, President of the Pennsylvania Railroad Company, joined the firm as special partner, and a younger brother of Mr. North as general partner, under the firm name of Norths, Harrison & Chase, who conducted a large foundry at Wilmington, Del., with sales-rooms in Philadelphia. In the following year, Mr. Harrison died, and the name was changed to North, Chase & North, and eventually Chase became the head of the firm of Chase, Sharpe & Thomson, the junior of which was Edgar L., a nephew of President Thomson. But although their house engaged in an extensive wholesale trade extending to foreign countries, the practical business element was somewhat deficient in the head of the house, who greatly preferred intellectual pursuits, and, after suffering heavy losses, he finally, in 1866, after having wasted eighteen precious years in uncongenial occupations, sold out his interest in the foundry business. He was at this time forty-six years of age. Prof. Chase has been criticised for too much diversification of pursuits. It was characteristic of this tendency, that for six or eight years prior to abandoning mercantile life, he had given private lessons in the then famous school for young ladies of Prof. Charles Dexter Cleveland; and five years earlier had actually bought the furniture and good-will of Prof. Cleveland, upon the latter's retirement from teaching. This course, while more to the taste of so intellectual a man, did not conduce to the success of the foundry business which he was conducting, and which afterwards, in the hands of a former employé, proved exceedingly profitable, although the closing years of Prof. Chase's connection were the lucrative years of inflation caused by the war of the Rebellion. In the very same year, he also gave up the finishing school for young ladies, his own impression being that "the breaking out of the war interfered with private schools." He did not, however, abandon teaching, and from this time until his death adhered to his chosen profession, pursuing it continuously, if we except two visits to Europe, on the first of which, in 1870, he accompanied a party of young ladies who had been his former pupils and who sought the benefit of his familiarity with the European languages, as well as his agreeable companionship. The second visit was made in the summer of 1883 with members of his own family.

His later days were certainly his best days as a teacher, and while a natural modesty stood in the way of ambition, and he preferred a quiet

and unobtrusive life, yet he attained a highly creditable standing in the profession. On the sixteenth of January, 1863, he was elected a member of the American Philosophical Society, to whose Transactions and Proceedings he afterwards became a diligent contributor. He occupied for a time the Chair at the University of Pennsylvania, rendered vacant by the death of Prof. Fraser, and, in 1871, became Professor of Natural Sciences in Haverford College, and remained a member of the faculty of that congenial institution until his death, occupying, after 1875, the Chair of Philosophy and Logic, then established. In 1876 he received the honorary degree of LL.D. from Haverford, on the ground of "his attainments and original researches in Mental and Physical Philosophy." Two years later, in the summer of 1878, after a severe illness, which resulted in the partial paralysis of one foot, and sensibly abated his physical vigor, he removed from Philadelphia to reside in the cottage on the beautiful grounds, in a bit of natural forest, adjoining the magnificent avenue of maples which forms the approach to Haverford College. On this charming spot, in the midst of sweet pastoral scenes, abounding in vegetable life, he had an excellent opportunity to indulge his taste for botany, a favorite pursuit. In 1884 he received the appointment of Lecturer on Psychology and Logic at Bryn Mawr College for Women. He prepared the syllabus and notes for the first course of lectures, which he was to have delivered in the winter of 1885–6, but was never able to deliver them, being overtaken by his final illness during that season. A sharp attack of pneumonia sapped the foundations of a vitality already much undermined, and although he partially recovered and resumed his duties at Haverford, the end was evidently drawing near. During the brief interval of life that remained and in consequence of the absence in Europe of his brother Thomas, who was President of Haverford College, he was made Acting President of that Institution, and held that position when death came, presiding at the Annual Commencement of 1886. His name had been prominently mentioned for the Presidency of Bryn Mawr College at the time of its organization, but the precarious state of his health forbade, although his eminent scholarship, the variety of his learning, and his previous experience in Young Ladies' Schools, strongly commended him for that position.

As a College Professor, he was clear in his demonstrations and attractive; and many are the testimonies of affection and respect borne by his former students, accompanied by acknowledgments of the important influence of his teachings upon their lives. As a disciplinarian, he was mild and easy, inspiring his pupils with love rather than fear; indeed the latter was not an ingredient in his system at all; he governed purely by gentle suasion.

Such is the simple record of a quiet life, the annals of which display no startling passages. If modesty were the opposite of greatness, then he was not great. But there was an unusual combination of great and good qualities in his mind and character, and one of its most conspicuous traits

was a rare simplicity, indeed genuine modesty and humility, which is oftenest closely allied to a true greatness in the soul, unconscious of itself and busied with lofty studies of omnipotent power and sublimity. It was through this beautiful quality, which was perfectly natural and unassuming, that he endeared himself much to all of his intellectual associates, whether pupils or companions of his own age.

He had a singularly versatile mind, and a comprehensive and richly furnished memory. His writings included a wide range of subjects, upon each of which he displayed much erudition, and they were full of suggestiveness. It is seldom that a like capacity is found in one mind, both as a linguist and as a mathematician. He read with the help of dictionaries, and was more or less familiar with one hundred and twenty-three languages and dialects, and claimed thorough acquaintance with thirty of them. His knowledge of these was not profound, nor was it marked by the accuracy, in pronunciation and otherwise, which familiar conversation requires. Yet his attainments as a linguist afford a remarkable indication of the scope of his mind and the extent of his memory, and therefore throw an important light upon our estimate of the value of his deeper and more characteristic productions. Occasional contributions to the Proceedings of the American Philosophical Society were made on subjects in Comparative Philology, as the paper "On Radical Etymology," that on the "Mathematical Probability of Accidental Linguistic Resemblances," on "Sanscrit and English Roots and Analogues," on the "Comparative Etymology of the Yoruba Language," and others. His reputation as an analyst was sufficient to induce the sending to him of an obscure cipher from the War Department for translation during the Rebellion, and, on another occasion, of a Coptic inscription. But although his philological attainments were in no wise mean, his pen was most fertile in other directions. Of over 150 papers contributed by him to various learned bodies, most of them to this Society, not more than one-tenth were philological, and the remainder mostly in meteorology, cosmics and physics. Many of these were fragmentary,—studies, as it were, of great themes,—and in undigested groups; they were unfinished, like Michael Angelo's marble groups, and needed the master's hand to give them the perfect expression intended. As he grew older, they took more and more a cosmical direction, and his mind struggled to demonstrate from the harmonies of the universe, as the geologist does from the marvelous narrative of the rocks, a cosmical evolution. Going back to the very sources of development with daring genius, he sought, through proofs of the "Quantitative equivalence of the different forms of force which we call light, heat, electricity, chemical affinity, and gravitation," and original theories of nodal accumulation, the truth of which time may affirm, to establish a common law that "All physical phenomena are due to an Omnipotent Power, acting in ways which may be represented by harmonic or cyclical undulations in an elastic medium." A peculiarity of his mental operations was a singular capacity for seeing harmonies and analogies

which did not attract the attention of others. His methods of thinking were swift, and led him to undemonstrated skips in his reasoning which made it difficult to follow him. In the ordinary processes of addition, he footed up columns of eight or ten numbers, extending into trillions, instantaneously, setting down the result from left to right, ending with the units. A certain instinctive or intuitive faculty pervaded his demonstrations, interrupting their purely mathematical character, and making many mathematicians and physicists plausibly skeptical as to the value of his theories.

An eminent scientist at one time spoke of him as "the Kepler of this century," and there was a certain resemblance, in the tentative methods pursued by him, to those by which his great prototype discovered the astronomical laws upon which his fame is based.

Prof. Kirkwood writes: "The just value of his contributions to science cannot at once be determined. It must be said, however, that his hypothetical conclusions were so often in close agreement with well-known facts, as to leave the impression that his theories must have a foundation in truth."

Prof. Herschell, referring to his paper on "The Results of Wave Interference," bears this testimony: "From a direction of research probably as distant and distinct as possible from the late Prof. Chase's, at least in its origin, I have reached results which the contents in this case, of Prof. Chase's papers, confirm and corroborate so amazingly, that all question of the real validity of views, however incongruous they may perhaps be to each other in particulars, by which identical results of such surprising characters have been arrived at by us both, in perfect independence, is banished completely and forever from my mind. Prof. Chase's writings and discoveries will constantly gain in note and consequence by wider and longer consideration and perusal; and they will surely never cease to have leading uses for consultation and for purposes of instructive study, among those who aim and strive to unmask more laws of energy's unitary operations, if possible as prominent and predominating as those which his discoveries have disclosed."

An American philosopher, who, while somewhat uncertain how to estimate him, says he is hopeful that the future will reveal the value of Prof. Chase's labors, speaks thus of his later work: "It may prove prophetic of developments that will take us a long step below our present philosophy of things—or it may not. Time will show. If the new developments do come, my feeling is, that they will help to bring the heavens and the earth nearer together, by showing that beneath the seemingly ultimate facts of matter, gravitation, conservation of work, things that may seem to pertain to no other life of ours than this—that beneath these, and nearer to the ultimate reality, there lies an order of things that may well serve as the physical basis of this and the next life alike."

Prof. Chase, although, as we have already said, very modest in his esti-

mates of himself, was confident that his conclusions pointed in the right direction. Yet he did not claim mathematical demonstration for his theories, and while his papers abounded in formulæ, they were only partly mathematical even in form. There was an element of imagination, of speculation and of intuition. The harmonies are not always perfect, links are missing; very probably some of them will prove to be accidental, while others, with their profound inductions, will remain firmly planted upon the rock of truth. Indeed, they have claims, not only to coincidence with the conclusions of other philosophers, derived from different data, and reached through other channels, but even to verification as predictions. Dr. Chase regarded the series of twelve papers contributed to the London, Edinboro' and Dublin Philosophical Magazine as containing, to quote his own words, some of his "most important discoveries in confirmation of the nebular hypothesis, including nine verifications of intra-mercurial planets and of harmonies of solar and planetary rotation that he had predicted some years prior to the discovery." These "verifications of intra-mercurial planets" should rather be designated "Confirmations from other sources of his opinion predicting them." These special articles comprised the 1. Cosmical Activity of Light; 2. Equilibrating Forces of the Solar System; 3. Planetary Interaction; 4. Our Binary Star and its Attendants; 5. Correlations of Central Force; 6. Ætherial Nodes; 7. Momentum and Vis viva; 8. Undulation; 9. Criteria; 10. Radiation; 11. Watson's Intra-mercurial Planet; and, 12. Predictions. The titles of these papers sufficiently indicate their character and his claims of original discovery, which are further elucidated by such others, appearing elsewhere, as "The Gamut of Light," "The Music of the Spheres," "The Beginning of Development," "Planeto-taxis," and "Photo-dynamic Notes." Regarding light as the primal manifestation of force, and the Almighty fiat, "Let there be light" as the order for movement in the cosmic element, out of which all the complex development of the universe has grown, he felt after and sought to discover the fundamental laws whose universal application might pervasively explain all material forms and forces. Thus his investigations were not limited to the relations of the great forces of light, gravity, electricity, etc., but his speculations on the harmonies extended to the laws which govern chemical affinity and to ordinary material things. This much may be said as to these investigations: that

1. Whatever may be the ultimate conclusions of Science as to the precise nature and extent of the evolution, there has been an evolution from the simpler and more comprehensive conditions of matter, into the more complex and multiform.

2. It is reasonable to suppose that this entire evolution has been in accordance with some general law.

3. The discovery of that law is probably within the reach of the human mind.

It was after this law that Prof. Chase was searching; the character of his

mind was one that eminently fitted it for the investigation; and future researches may show his work to have been founded in fact and correct inference, and that he was in advance of his age and above the heads of his critics. The respect in which his writings have been held in Great Britain has been attested by their publication in the "Philosophical Magazine." His essay on "The Numerical Relation between Gravity and Magnetism" received, in 1864, the Magellanic Premium from this Society.

The detached and fragmentary character of his scientific productions, their real profundity, and the limited number of those who could follow him in his rapid evolution of thought on these subjects, have led many scientific men to regard his speculations with doubt, and some, who had little or no personal acquaintance with their author, accord them no scientific value. But Prof. Chase was least of all a hypocrite or a charlatan, and those who knew him best will most unhesitatingly recognize his deep sincerity. He was an humble seeker after truth, with the lamp of a strong intellect. The obscurity of his logic belongs not altogether to the writer, but to his theme. There was nothing obscure about his ordinary style. When he wrote upon familiar topics it was clear and cogent, rising sometimes into flights of eloquence. It is to be regretted that he has not himself been able to put into compact and comprehensible form his studies on cosmical and molecular forces as applied to astronomical and interplanetary relations, and no less the profound, though fragmentary notes, which his mind threw off in later scintillations. But they were not completed, and though much more than gropings after the facts of infinity, can not lay claim to perfect and final demonstration. Whatever title his name has to rank among the greatest on the rolls of science, however, no one who knew his work will deny him an eminent place.

The loftiness of conception and inspiring suggestiveness of his writings, his extensive learning, his great industry and productiveness, his boldness and success in dealing with the problems of the unknown world, entitle him to distinction. Aside from his deeper and favorite themes, the range of subjects ably treated by his pen was notable. Among these may be remarked such familiar topics as Bricks, Paper, Ink, Ceramics, Artificial Iron Works.

Some of his rules for weather prediction were embodied by the U. S. Signal Service in its "Manual for Observers," and the observations of the Bureau have indicated the importance of anti-cyclonic storm centres, to which he first called attention. He claimed the discoveries of "a parabolic connection between the nearest fixed star and the solar system, of harmonic undulations which have influenced the arrangement of planets and of spectral lines, and of the quantitative equivalence of the different forms of force." He made many observations upon rainfall, and in a series of papers, "demonstrated the meteorological influence of the moon," regarding "the evidence of important lunar modifications, both in the amount and in the frequency of rain, as unmistakable."

A leading characteristic of Prof. Chase was the quiet and unwavering faith with which he adhered to the Bible record, and to Evangelical Christianity. Through all mutations, throughout his active studies of the material world, and of the great forces of Nature, he was unshaken in his belief in the spirituality of religion, and its real and necessary relation to the same Omnipotent Power, who originated the cosmos. He accepted the Christian theory of salvation absolutely and without qualification as Divine. That which many scientists are led to doubt, seemed clear to him, and all facts were of necessity parts of one stupendous whole. He was a religious man, not only by intellectual conviction; but the fruits of piety were manifest in his daily life, especially towards its end, in an unaffected gentleness and sweetness of temper, a freedom from assumption, and a general submission of his actions to the Divine government and guidance. Wealth had few attractions for him, his tastes inclining him to count it loss if it interfered with science and religion, even if he had had any gift for accumulating, which he had not. Born in the Society of Friends, he held throughout life their belief, and of later years frequently preached to the little congregation at Radnor, of which the Haverford students and Professors formed a part. Nor was his pen idle upon religious themes, and those affecting the prosperity of the sect he loved. He read an able paper before this body on "The Philosophy of Christianity," and his lecture "On Denominational Education in the Society of Friends" was a lucid argument of much power in its favor. He was wont to press the view that God was ever acting on the soul of man to give it right direction, as well as in the phenomena of nature. His faith was not so much in doctrinal propositions, as in God himself, as revealed in Christ, in Nature, in History, and in Man's reason and conscience. But while firm in his own convictions, he was broad and charitable to others, and sought to find any ground of common truth upon which he and those who differed most widely from him could stand. His opinion was candid, and open daily, like Dr. Arnold's, to change with the advances and discoveries of science; yet he always retained an abiding confidence that Science and Revelation would be found really to harmonize. His personal trust in a present Omnipotence enabled him to meet all the vicissitudes of fortune with a more than philosophic composure and content. While his philosophy was pervaded with religion, his religion was no less filled with philosophy, and the lustre of his life presents a shining example to those who survive him of evolution "more and more unto the perfect day," when at last the "mortal shall have put on immortality."

Octonary Numeration, and its Application to a System of Weights and Measures. By Alfred B Taylor, A.M., Ph.M.

(*Read before the American Philosophical Society, October 21, 1887.*)

For many years strong and persistent efforts have been made by the advocates of the French metrical or decimal system, to have its use made obligatory in the United States, to the exclusion of the heterogeneous tables of weights and measures now existing. Its use has been legalized in Great Britain since 1864, and in the United States since 1866.

"On the first of January, 1879, a new Act went into force," (in England) "by which it is made unlawful to buy or sell by other than imperial measures, and no provision is made for the adoption of the metric system."*

Its progress in either country has been very slow.

At the meeting of the British Association for the Advancement of Science in 1887, Mr. Ravenstein, of the Geographical section, while strongly advocating the metric system, stated that "while the English foot is used by 471 millions of people, the metre is used by only 347 millions of people." But the selection of a system evidently should not be made because a greater number of people use the one or the other, nor on account of the cost of the change in money or in temporary inconvenience, but it should be made on the intrinsic merits of the system.

The zealous votary of the metric system can acknowledge no defects; the offspring of the world's best science, it must be as perfect as it is beautiful, and only prejudice, ignorance and stolidity can stumble on obstructions, or refuse entire allegiance to its beneficent sway. The real difficulties in the way of its success are fully realized alone by those who have given a careful and unbiassed attention, not merely to the various schemes proposed for simplifying or harmonizing national weights and measures, but to the practical operation of such reforms when actually applied to the daily life of human masses. And thus it occurs that what to the enthusiast is the foremost virtue of the French system, is, in the view of the thoughtful student of facts, its most insuperable disadvantage.

The objections to it have been sufficient up to the present time to prevent its adoption, and it is the opinion of very many persons that it can *never* be satisfactorily adopted.

Many different projects in remedy of the existing and acknowledged evils have been suggested; some more practicable, others more systematic; and unfortunately these two classes appear to bear an inverse ratio to each other.

The substitution of decimal multiples and divisions, conformably to our established arithmetical notation, has been advocated; and various standards or units have been proposed, such as the inch, the foot, the grain, the

* "*New Remedies*," Vol. viii, p. 192. New York, 1879.

pound, the pint, the gallon, the cubic inch, the cubic foot, etc., but none of these projects has met with much favor.

The most feasible plan for arriving at a satisfactory and authoritative determination of so vital an issue would appear to be the appointment of an international commission, with England, Russia and the Germanic States (with France as well, if practicable), comprising the highest representative talent, not alone from the ranks of the physical philosopher and geometrician, but as well from the classes of merchants, machinists and civil engineers; from those most interested and most skilled in the subject, for the purpose of organizing and developing an acceptable and permanent system of weights and measures.

Among the labors of such a commission, a very needful one would be to institute a careful and impartial investigation into the exact state and working of the metric system among those nations which had tried it. Assuming nothing, rejecting nothing, accepting nothing, as the groundwork of the future, the commission should endeavor, from a comprehensive survey of all the conditions and all the possibilities involved, to elaborate a scheme best suited to the wants of man, and therefore best entitled to the acceptance of the nations.

If the final verdict were in favor of a uniform octonary system, it would not be difficult to establish it. If, on the contrary, such a commission should agree to adopt the present French system, their decision would go far to silence all further discussion; the result would be well worth the labor and delay it might cost. No people would receive the system with greater alacrity, or master its details with more facility and promptitude than those of the United States; not merely from their general intelligence and mental versatility, but from their long training in the use of their decimal monetary system.

Such a conference among nations having so many fraternal ties, seems to be eminently proper in every sense, and surely will not be regarded, at this day, as a visionary or illusive expectation.

The origin of weights and measures is not known, and can be only conjectured. Their need was contemporaneous with the infancy of the human race.

Man in a state of nature would, in his strife for existence, seek food, clothing and shelter from the inclemency of the weather. He would kill animals for their flesh, and use their skins for clothing. The adaptation of skins to this purpose would require measures of some kind to be used. Those naturally suggesting themselves would be the finger, the breadth of the hand, the span, the cubit (or extent from the tip of the elbow to the end of the middle finger), the arm, and the fathom (or extent from the extremity of one middle finger to that of the other, with extended arms). So in the construction of a habitation, however rude, whether of logs, or of earth and stones, he would find need for the use of measures, and some of the above would no doubt supply his needs. Distances traversed in his walks about his habitation would naturally suggest to him measures

of length, and none of those mentioned would conveniently supply his want. Here he would probably use the foot or the pace, and it would not naturally occur to him to use the same measure, or the same scale of proportions and numbers to clothe his body and to mark the distance of his walks. Here, then, is a source of diversity in the standards of linear measure, flowing from the difference of relations between man and physical nature. It would be as inconvenient and unnatural to measure a bow and arrow, for instance (among the first implements of solitary man), by his foot or pace, as to measure the distance of a day's journey, or a morning's walk to the hunting ground, by his arm or hand. These natural standards are never lost to individual man in any stage of society. There are probably few persons living who do not occasionally use their own arms, hands and fingers to measure objects which they handle, and their own pace to measure a distance upon the ground.

The need of measures of capacity would not be felt at quite so early a period of man's history as measures of length, yet they would be rendered necessary by the nature of liquids, and for the admeasurement of those substances which nature produces in multitudes too great for numeration, and too minute for linear measure; of this character are all the grains and seeds, which from time to time, when man becomes a tiller of the ground, furnish the principal materials of his subsistence. But nature has not furnished him with the means of supplying this want, in his own person, and as his first measures of capacity he would probably employ the egg of a large bird, the shell of a mollusk, or the horn of a beast. The want of a *common* standard not being yet felt, these measures would be of various dimensions; nor is it to be expected that the thought would ever occur to the man of nature, of establishing a proportion between the size of his arm and his cup, of graduating his pitcher by the size of his foot, or equalizing its parts by the number of his fingers. The necessity for the use of weights comes still later. It is not essential to the condition or comforts of domestic society. It presupposes the discovery of the properties of the balance; and originates in the exchanges of traffic after the institution of civil society. It results from the experience that the comparison of the articles of exchange, which serve for the subsistence or the enjoyment of life, by their relative extension, is not sufficient as a criterion of their value. The first use of the balance and weights implies two substances, each of which is the test and standard of the other. It is natural that these substances should be the articles most essential to subsistence. They will be borrowed from the harvest and the vintage; they will be corn and wine. The discovery of the metals, and their extraction from the bowels of the earth, must, in the annals of human nature, be subsequent, but proximate, to the first use of weights; and when discovered, the only mode of ascertaining their definite quantities will soon be perceived to be their weight. That they should themselves immediately become the common standards of exchanges, or otherwise of value and of weights, is perfectly in the order of nature; but their proportions to

one another, or to the other objects by which they are to be estimated, will not be the same as standards of weight and standards of value. Gold, silver, copper and iron when balanced each by the other in weight will present masses very different from each other in value. They give rise to another complication, and another diversity of weights and measures. The balance, or scales, in a rude form, are known to have been in use from very early times. The Greeks, as appears from the Parian chronicle, believed weights, measures, and the stamping of gold and silver coins to have been alike the invention of Phidon, ruler of Argos, about the middle of the eighth century B. C.

The weights or counterpoises used in weighing were probably obtained by taking equal bulks, roughly determined, of some material of comparatively uniform density, such as brass or iron; but to render them more accurate and definite it became necessary to call in the aid of more accurate measures of capacity; and the weight of a known volume of pure water, at a known density, is now the criterion universally resorted to for determining the standard of weight. This supposes that the volume or cubic contents are correctly known; and since contents or capacity can be practically expressed only in terms of the cube of a length, and area in terms of the square of a length, it follows that to obtain exact units of measure of all kinds, it is necessary first to fix, and then to be able to reproduce with the greatest possible exactness, the unit of length. Absolutely invariable standards of weight and measure have not been, and in the nature of the materials to be dealt with, cannot be attained; while to secure and reproduce measures of given sorts, the results of which shall be correct and uniform to within the least practicable degree of variability, is a problem upon which a vast amount of scientific research, ingenuity and labor has been expended.

When the legislator has the subject of weights and measures presented to his contemplation, and the interposition of law is called for, the first and most prominent idea which occurs to him is that of uniformity; his first object is to embody them into a system, and his first wish to reduce them to one universal common standard.

In England, from the earliest records of parliamentary history, the statute books are filled with ineffectual attempts of the legislature to establish uniformity.

Of the origin of their weights and measures, the historical traces are faint and indistinct; but they have had from time immemorial, the *pound*, *ounce*, *foot*, *inch* and *mile*, derived from the Romans, and through them from the Greeks, and the *yard*, or *girth*, a measure of Saxon origin, but as a natural standard different from theirs, being taken not from the length of members, but from the circumference of the body, and hence a source of diversity. The yard, however, very soon after the Roman conquest, is said to have lost its original character of girth; to have been adjusted as a standard by the arm of King Henry the First; and to have been found

or made a multiple of the foot, thereby adapting it to the remainder of the system.

In 1266, the first positive attempt was made to change the common weight into the troy,* under the name of the weight of assize; a statute 51. Henry III enacted "that an English penny called a sterling round, and without any clipping, shall weigh 32 grains of wheat, from the middle of the ear, and 20 pence to make an ounce, 12 ounces a pound, 8 pounds a gallon of wine, and 8 gallons of wine a bushel of London, which is the eighth part of a quarter." This penny weight was divided into 24 grains.

But neither the present avoirdupois, nor troy weights, were then the standard weights of England. The foundation of the system of 1266 was the penny sterling, which was the 240th part of the *tower pound;* the sterling or easterling pound which had been used at the mint for centuries before the conquest, and which continued to be used for the coinage of money until the eighteenth year of Henry the Eighth, 1527, when the troy pound was substituted in its stead. The tower pound weighed 360 grains (or $\frac{1}{16}$) less than the pound troy, and the penny, therefore, weighed $22\frac{1}{2}$ grains troy.

The philosophers and legislators of Britain have never ceased to be occupied upon weights and measures, nor to be influenced by the strong desire for uniformity. They found a great variety of standards differing from each other, and instead of searching for the causes of these varieties in the errors and mutability of the laws, they ascribed them to the want of an immutable standard from nature. They felt the convenience and the facility of decimal arithmetic for *calculation;* and they thought it susceptible of equal application to the divisions and multiplications of *time, space* and *matter.* They despised the primitive standards assumed from the stature and proportions of the human body. They rejected the secondary standards taken from the productions of nature most essential to the subsistence of man; the articles for ascertaining the quantities of which weights and measures were first found necessary. They tasked their ingenuity and their learning to find, in matter or in motion, some *immutable* standard of linear measure which might be assumed as the single universal standard, from which all measures and all weights might be derived. In France their results have been embodied into a great and beautiful system. England and America have been more cautious.

Among the earlier measures of length used by various nations are found such as the "finger's length," the "digit" (second joint of the forefinger), the "finger's breadth," the "palm," the "span," the "cubit" (length of forearm), the "nail," the "orgyia" (stretch of the arms), the "foot," the "pace," etc., and the names of these measures,

* When the troy weight was introduced into England is not known. It was introduced into Europe from Cairo in Egypt about the time of the Crusades, in the 12th century. Some suppose its name was derived from *Troyes*, a city in France, which first adopted it; others think it was derived from *Troy-novant*, the former name of London.

their almost constant recurrence among different nations, and the close approximation in length of such as have, like the foot, more nearly acquired the character of arbitrary measures, alike establish the fact that in its origin, measurement of length was by the application of parts of the human body. In some parts of the East the Arabs, it is said, still measure the cubits of their cloth by the forearm, with the addition of the breadth of the other hand, which makes the end of the measure; and the width of the thumb was in like manner formerly added at the end of the yard by the English clothiers. The advantages of such measures for popular use are that they are known by observation and readily understood, and in an average way always capable of being recovered, when more arbitrary standards might be wholly lost. But their great disadvantage is extreme variableness, especially when directly applied; and in the gradual progress of men's minds toward exactness of conception and reasoning, three successive plans of insuring greater accuracy have been devised, and two at least have secured permanent adoption.

The first is that of obtaining a uniform standard by exchanging the measures by parts of the body for conventional or arbitrary lengths, which should represent the average, and which were to be established by law.

The second plan is that of making accurate comparisons of the various standards of each given sort in a country. Attempts of this kind appear in England to have been commenced under the auspices of the royal society in 1736 and 1742; in the former year by a comparison of the English, French and old Roman standards; and in the latter by the determination (by George Graham) of the length of a pendulum beating seconds at London, to be equal to 39.1393 inches, and the construction of a standard yard. Of this, under the direction of the House of Commons, Mr. Bird (a celebrated optician) prepared two accurate copies, respectively marked "standard yard 1758" and "1760," and intended for adoption as the legal standards. He determined and prepared also the pound troy, the original of that now in use. Of these two standards, no intentional alteration has since been made; so that these or their derivatives are now in use in England and the United States.

The third proposed step toward rendering measures exact has reference rather to the means of making the standards recoverable in case they should be lost. In the definite pursuit of this purpose the French philosophers of the time of the Revolution took the lead, and devised the metric system, in which the unit of length is derived from the dimensions of the earth, and the units of capacity and weight are made dependent upon the former, while the whole has decimal multiples and subdivisions. The celebrated commission concentred within itself the physical and mathematical science of France, but there was one science unfortunately not there represented; the science of human nature. Looked at from a purely arithmetical standpoint, the problem of measures suggested but one solution, that of the decimal digits. Abstract mathematics could furnish no inducements to binary or octonary divisions or progressions.

So early in our national existence as the year 1790, the illustrious Jefferson, then Secretary of State, in obedience to a resolution of Congress calling upon the Secretary to propose a plan or plans for establishing uniformity in the currency, weights, and measures of the United States, presented a report recommending a decimal system of metrology, and its derivation from a natural and permanent standard of length.

Instead of taking the ordinary pendulum of 39 inches, he proposed the second's rod of 5 feet, then generally known as Leslie's pendulum rod. A simple straight rod, without the bob or ball, suspended at one end, has, as is well known, its centre of oscillation at a distance of two-thirds of its length from its point of suspension; or, in other words, is one-half longer than the common loaded pendulum vibrating in the same time. Such a rod vibrating seconds is 58.72368 inches long; dividing this into five equal parts, Mr. Jefferson took this fifth part, or 11.744736 inches as the length of the new "foot," and from this by decimal multiples and subdivisions he presented a series of tables of weights and measures.

When we reflect that the system of metrology here displayed was perfected by Mr. Jefferson before any steps had been taken by the French government toward the decimal re-organization of weights and measures in that country, we must regard it as a memorial in the highest degree creditable to the judgment and contriving skill of its author; and as one of many illustrations of the varied activity of his mind, and of the interest he ever felt in all schemes for human improvement. The great superiority of his proposed scales of measure, to those in common use, cannot be questioned; and their adoption would have been a signal public benefit. The tables presented by him form a connected and complete system, each depending directly upon the one preceding, and necessarily flowing out of it, and all determined from a single and invariable natural standard by a very simple and beautiful mode of derivation.

In this respect, however, the French system is by far the best of all that have yet been devised. Starting with a carefully measured quadrant of the earth's meridian, and dividing it into ten million parts, this system presents us with a "metre"* as a universal standard to which all others may be referred. Indeed, if a decimal system of weights and measures is to be ultimately adopted, there appears to be none that has such just claims to our acceptance as that of the French; and although it would be much more difficult of popular introduction than a simple decimalization of our own divisions, and therefore less "practicable," there can be no doubt that it would be in every way superior, both in regard to the precision of its measures, and the simple and philosophical character of its divisions; besides all which it has the immense advantage of being already introduced and in successful practical operation throughout the great Republic of France; and every extension of its use would be an important step in the progress toward a uniform system among all nations.

* Equal to 39.370788 inches; very nearly the length of the second's pendulum, and not much longer than our yard.

Beautiful and simple as this system appears, and clear as its nomenclature is to those familiar with the Greek and Latin tongues, it is yet open to animadversion on practical grounds, in that its language is that of the philosopher, and not of the tradesman or the business man. To all but classical scholars—that is, to the large majority of men—the terms used in the French tables are difficult and unmeaning; to be acquired and appreciated only by a laborious effort of abstract memory, and even when thus acquired, constantly liable to be confounded and mistaken. Its metres and litres, its myriametres and myrialitres, its decigrammes and decagrammes, are admirably contrived to bewilder the uninitiated, but of all possible devices are the least adapted to the common uses of daily life. To obtain a ready and direct apprehension of the values of different denominations of measure, it is necessary that each should be recognized as an independent unit, without reference to its fractional or multiple derivation. Thus, "ounces" or "inches" are at once seized upon by the mind as distinctive standards of value; and the fact that these terms both signify "twelfths" (being derived from the Latin "uncia") never enters into our contemplation when using them. The coin a "cent" has come to signify a "one" and not a "hundredth." What is really needed then for the popular service, is a set of names, brief, easy, and distinctive by a wide separation of sound, however arbitrary or unmeaning may be their origin. In this view of the matter, the rude and indefinite vulgarisms of "grains" and "scruples," "feet" and "rods," "gills" and "gallons" are infinitely preferable to the scientific jargon of *centigrammes* and *milligrammes*, and *hectogrammes* and *kilogrammes*. In fact, the French system has totally ignored all units, excepting the single one selected as the standard for each table. Thus in weight, the French cannot be said to have any other measure than the gramme; and instead of resorting to the dead languages for so familiar a thing as a simple numeration table, it would be much better to speak of and write down, the multiples or divisions of this weight as a thousand or a hundred grammes, or as so many hundredths or thousandths of a gramme. This, in plain English (or plain French), would be understood by every one, and would just as conveniently express everything that is contained in the high-sounding terms we have characterized as "scientific jargon."*

An almost unmanageable difficulty in the introduction of the French

* While thus strongly expressing our objection to the *nomenclature* of the French tables (whose very fault is its excess of system), it would be unjust not to acknowledge, and ungenerous not to admire, the catholic sentiment which dictated it. The eminent philosophers to whom belongs the honor of developing a metrology by far the most perfect that has yet been devised, felt as if they were legislating for the civilized world. Desirous that all might have the benefit of their labors, they rejected all the familiar terms employed in France, and naturally resorted to the great storehouse from which the scientific world has ever been accustomed to draw its technical phraseology; exhibiting in this, their anxiety to adopt a language which might be acceptable to all nations. Unfortunately it is suited to none. The language of science cannot be that of the shop and the market-place.

system has been found in the adoption of the nomenclature; there is a natural aversion in the mass of mankind to the adoption of words, to which their lips and ears are not from their infancy accustomed. Hence it is that the use of all technical language is excluded from social conversation, and from all literary composition suited to general reading; from poetry, from oratory, from all the regions of imagination and taste in the world of the human mind. The student of science in his cabinet easily familiarizes to his memory and adopts without repugnance words indicative of new discoveries or inventions, analogous to the words in the same science already stored in his memory. The artist, at his work, finds no difficulty to receive or use the words appropriate to his own profession. But the general mass of mankind shrink from the use of unaccustomed sounds, and especially from new words of many syllables.

Should these measures be therefore introduced, we should strongly urge the entire abolition of the French nomenclature, and the complete naturalization of the different scales by the substitution of more familiar terms from our vernacular tongue.

In the advancement of physical science no nation has taken a higher position, or exhibited a more fertile activity, than France. Hence it has become necessary for every English and American physicist to familiarize himself with the French units and standards of scientific research and discovery, if he would avail himself of their benefits or information. This again has induced a considerable employment of the same scales by the English and American *savants*, in repeating or extending the foreign experiments. It is not remarkable, therefore, that the scientific world generally, both in this country and in England, should desire to see this system universally prevail. Very few scientific men have given the subject of popular weights and measures any special attention, and of those who have, it is believed that a very small proportion will be found to advocate the unqualified adoption of the metric system.

A decimal system applied to weights and measures must result in failure as regards the convenience of such a system or its adaptation to popular wants, and this want of adaptation arises, not from any defect in the plan on which it is established, but from inherent defects in the decimal system of numeration.

The introduction of any new system of weights and measures, to take the place of one long established and in general use, will be found a troublesome and difficult exercise of legislative authority. There is indeed no difficulty in enacting and promulgating the law, but the difficulties of carrying it into execution are always great.

Of all the difficulties to be overcome, however, perhaps the greatest is the abandonment of old and familiar units or standards.

"Weights and measures may be ranked among the necessaries of life to every individual of human society. They enter into the economical arrangements and daily concerns of every family. They are necessary to every occupation of human industry; to the distribution and security of

every species of property; to every transaction of trade and commerce; to the labors of the husbandman; to the ingenuity of the artificer; to the studies of the philosopher; to the researches of the antiquarian; to the navigation of the mariner, and the marches of the soldier; to all the exchanges of peace, and all the operations of war. The knowledge of them, as in established use, is among the first elements of education, and is often learned by those who learn nothing else, not even to read and write. This knowledge is rivetted in the memory by the habitual application of it to the employments of men throughout life. Every individual, or at least every family, has the weights and measures used in the vicinity and recognized by the custom of the place. To change all this at once, is to affect the well-being of every man, woman and child in the community. It enters every house, it cripples every hand."

The failure that attends the introduction, and the objections that have so far prevented the adoption of the metric system in Great Britain and in the United States, notwithstanding the strenuous and untiring efforts of its advocates, sufficiently attest the need of some other scheme, which, while possessing the advantages claimed by that, may be free from its disadvantages and defects.

Great Britain has shown such a determined opposition to the metric system, that, in the International Monetary Conference held in Paris in 1867, she refused even to negotiate in reference to unity of coinage, and her delegates stated "that until it should be incontestably demonstrated that the adoption of a new system offered superior advantages justifying the abandonment of that which was approved by experience and rooted in the habits of the people, the British government could not take the initiative in assimilating its money with that of the Continent."

She maintains the most complex system of measures, weights and coinage now in use among civilized nations; she persistently rejects the decimal system and adheres to the complex division of pounds, shillings and pence, a system abandoned by the United States in their rejection of colonial dependence.

A very strong objection to accepting the metre, either directly or indirectly, as our national standard of length is the want of absolute precision in the rule itself. It has been shown by the investigations of able mathematicians, that the metre is not an exact expression of its theoretical value, and as the result of more extended geodetic measurement up to 1875, that the quarter of the meridian is equal to 10,001850 metres, and that consequently the metre is too short by $\frac{1}{5400}$ part of its length. This unfortunate and vital defect in the French metre nullifies almost entirely its value as a natural standard, and defeats the principal object of its establishment—the facility of its perfect restoration in all future time should the existing material standards be destroyed. The metre is just as arbitrary a standard as the yard; the only real thing about it is the platinum rod in the public archives in Paris, and this has no advantage over the English standard kept in the British exchequer.

PROC. AMER. PHILOS. SOC. XXIV. 126. 2M. PRINTED NOV. 21, 1887.

The kilogramme has in like manner been found to differ from its assumed value by some small fraction, in consequence of the great difficulty attending exact determinations of this kind.

Our weights, measures and coins at present correspond much more nearly with the English than with the French standard. Our commerce with Great Britain is very much greater than with any other nation, and we should certainly commit a great error in adopting the metric system unless Great Britain should consent to adopt it also.

Our adoption of the metric system, and the consequent change of our linear unit, would sever our uniformity with Great Britain, a country with which perhaps three-fifths of our foreign commerce is transacted, besides which it would entail great inconvenience and much greater expense than is generally imagined. The measurements of every plot of ground in the United States have been made in acres, feet and inches, and are publicly recorded with the titles to the land according to the record system peculiar to this country. What adequate motive is there to change these expressions into terms which are necessarily fractional, and in which those foreign nations, whose convenience it is proposed to meet, have no conceivable interest? What useful purpose is subserved by designating a building lot 20 × 100 feet in the form 6.095889 × 30.479448 metres?

Besides this, the industrial arts during the last fifty years have acquired a far greater extent and precision than were ever known before. Take, for instance, the machine shop, in which costly drawings, patterns, taps, dies, rimers, mandrils, gauges and measuring tools of various descriptions, for producing exact work, and repetitions of the same with interchangeable parts, are in constant use. It has been calculated that in a well-regulated machine shop, thoroughly prepared for doing miscellaneous work, employing two hundred and fifty workmen, the cost of a new outfit adapted to new measures would be not less than one hundred and fifty thousand dollars, or six hundred dollars per man.*

Supposing full consent were obtained for using metric measures in all new machinery, how slow and difficult would it be to make the change. A very large proportion of work consists in renewing worn parts; where, then, are the new measures to come in? The immense plant of railway motive power in the United States is all made to inches and parts. At what time can a railway company afford to change the dimensions of the parts of a locomotive engine? At no time, because the change would require to be simultaneous in the whole stock. It is true that the old dimensions might be adhered to, and called by metric names, putting 0.0254 metres, or 25.4 millimetres for one inch; but this would be only an evasion, not a solution of the problem.

A practical defect in the working of this system, which has been demonstrated by experience, is its incapability of binary divisions; a defect which of course attaches equally to every decimal scale; and one which

* "The Metric System in our Workshops," etc., by Coleman Sellers. Journal of the Franklin Institute, Philadelphia, June, 1874.

has always strikingly displayed itself wherever this scale has been brought into popular use, for the estimation either of lengths, bulks, weights or values. In our own country the decimal scale has been applied only to the currency, and we find that in spite of the legal division of the *dollar* into tenths, and its seeming establishment by the coinage and circulation of *dimes*, the people persist in cutting it up into quarters, eighths, sixteenths, and even thirty-seconds, to the utter neglect of the coins actually established by law, and to the inconvenience, confusion, and loss, resulting from the necessary involvement of interminable and unmanageable fractions.

For all the transactions of retail trade the eighth and sixteenth of a dollar are among the most useful and convenient divisions, and although our government has never coined them, their want has been continually felt, thereby showing the insufficiency of our much admired and boasted decimalization of moneys to meet the actual wants and necessities of trade and daily business life. So far, therefore, from our decimal currency possessing the excellencies that have so often and so inconsiderately been ascribed to it, it has but the single merit of facility of computation. A single division of the number 10 brings us at once upon a prime number; and as the twelve pennies of the English shilling are far more convenient to the tradesman, than the 10 cents of the American dime, so the 12 inches of our present foot can never be usefully replaced by the 10 centimetres of the decimetre.

Many have supposed that this is all a matter of practical indifference, and that it merely requires the decisive sanction of legislative authority to accustom a people to any set of subdivisions. Such an opinion, however, exhibits both a blindness to the lessons of all experience, and an inattention to many of the most important and subtle theoretical considerations affecting the relations of value and our apprehension thereof.

Binal progression may be regarded as pre-eminently the natural scale of division. This fundamental fact is indeed illustrated in the very origin of the word *division*. The binary scale is in the first place the lowest and simplest of all the geometrical progressions. It is that of which we have the most ready and precise conception; indeed, it may be said to be the only one of which we have any accurate appreciation beyond the second or third term.* It is that by which we most rapidly and nearly approach any vague quantity we may desire to employ; hence its universal use in trade. It is that which in any system of independent units of measure (as in weights, or coins) furnishes us with the means of representing the greatest range of particular values, by the smallest number of pieces. It is that which affords us the easiest practical measure; thus we can fold a string, a sheet of paper, or any other flexible material, or we can cut an apple, or a loaf bread, at once and

* Thus, 1, 2, 4, 8, 16, 32, 64, etc., can be readily apprehended as repeated doublings, while 1, 3, 9, 27, 81, etc., leave the mind confused in the attempt to follow up successive triplings.

with great precision into halves, quarters, and eighths, while we should have to make repeated trials to divide the same into thirds or fifths, and then attain the result only tentatively and approximately. And lastly, it appears to be the most natural of scales, from the very common use of the two hands in separating objects into pairs.*

Such being the claims, then, of the binary scale of geometrical progression, and such its obvious advantages over all others, it is not surprising that this should be found to be practically the prevalent mode of distributing the more common weights and measures throughout the world, whatever may be the multiples or divisions enacted by law.

The Roman weights in general use throughout the empire (that is, throughout the civilized world) for some centuries after the Christian era, were by means of intermediate subdivisions (introduced by the common consent of traders) practically distributed upon a binary scale. So with the divisions in universal use at the present day; we find that a nest of avoirdupois weights comprises ¼ oz., ½ oz., 1 oz., 2 oz., 4 oz., 8 oz. and 16 oz., or 1 pound, and sometimes a 2-pound weight and a 4-pound weight; and by this scale of binal progression or division, almost everything is purchased at retail. Our yardsticks are found to be divided not into the legal feet and inches, but into halves, quarters, eighths and sixteenths. Precisely so with the inch, which is never divided into its primitive "three barleycorns," but almost always, like the yard, by the binal scale into eighths and sixteenths, though occasionally divided for particular purposes into twelfths, or into tenths. The operation of this great law is quite as strikingly exhibited in France, where the popular necessities have compelled the introduction of binal divisions, not recognized by the established decimal scales, nor, indeed, strictly compatible therewith.

Mr. Peacock, in his admirable treatise on "Arithmetic," in the *Encyclopedia Metropolitana*, thus sums up his review of the French system: "The decimal subdivision of these measures possessed many advantages on the score of uniformity, and was calculated to simplify, in a very extraordinary degree, the arithmetic of concrete quantities. It was attended, however, by the sacrifice of all the practical advantages which attend subdivisions by a scale admitting of more than one bisection, which was the case with those previously in use; *and it may well be doubted whether the loss in this respect was not more than a compensation for every other gain.*" This deliberate judgment is from the author of perhaps the

* "The classification by pairs which nature points out would suggest the simplest mode of reckoning. Counting these pairs again by two, and repeating the procedure, we arrive by progressive steps at the radical terms, 4, 8, 16, etc." (*Edinburgh Review* for May, 1811, Vol. xviii, p. 185).

The celebrated Leibnitz, so eminent as a mathematician as well as a philosopher, struck with the simplicity and peculiar capabilities of this scale, proposed and strongly urged the introduction of Binary Arithmetic. He showed that the Binary system, in addition to its extreme facility, possessed peculiar value in discovering the properties of numbers, and in constructing tables, etc. He did not, however, recommend it for general use, from the increased number of figures required to express ordinary amounts.

most thorough and philosophical treatise on arithmetic in our language, and such a statement certainly deserves our most serious consideration.

The masterly and comprehensive report on the subject of weights and measures, made to Congress in 1821 by Mr. Adams, when Secretary of State, contains the following judgment: "The experience of France has proved that binary, ternary, duodecimal and sexagesimal divisions are as necessary to the practical use of weights and measures, as the decimal divisions are convenient for calculations resulting from them; and that no plan for introducing the latter can dispense with the continued use of the former. * * * From the verdict of experience, therefore, it is doubtful whether the advantage to be obtained by any attempt to apply decimal arithmetic to weights and measures, would ever compensate for the increase of diversity which is the unavoidable consequence of change. Nature has no partialities for the number ten; and the attempt to shackle her freedom with them will forever prove abortive."

So in the interesting paper of Dr. Ellis (in the *American Journal of Pharmacy*, Vol ii, page 202), the French decimal system is thus referred to: "Every one is struck, at the first glance of this system, with the beautiful simplicity which it derives from decimal arithmetic. It appears, however, to have been overlooked, that, although decimal arithmetic is admirably designed to facilitate the calculation of mere number, it is not equally well suited to the divisions of material things."

Much to the same effect has been the result of the commission appointed lately in England to consider the subject of a decimal coinage. The commissioners, after a full discussion and investigation of the subject, have very recently reported against any change; their report being drawn up in the form of a series of twelve resolutions. The seventh resolution is as follows: "That as regards the comparative convenience of our present coinage, and of the pound and mill scheme, for the reckonings of the shop and the market, and for mental calculations generally, the superiority rests with the present system, in consequence, principally, of the more convenient divisibility of 4, 12, and 20, as compared with 10, and the facility for a successive division by 2; that is, for repeated halving, in correspondence with the natural and necessary tendency to this mode of subdividing all material things; and with the prevalence of binary steps in the division of our weights and measures."

In the view, then, of this pervading law or principle of all human metrology, so well established, and so distinctly recognized, it becomes an obvious necessity, in adopting a decimal scale, to engraft upon it, the divisions of halves and quarters, at least (and in the case of the more commonly employed units, of eighths), if we would adapt it to the demands of the people, or if we would hope for its permanent establishment. It is true that this would involve a considerable number of subordinate divisions between one denomination of measure and the next below it, as it would be requisite to have separate and distinctive weights, for instance, for the unit (whatever it might be) for one and a quarter of

the unit; for two, for two and a half, and for five; and it is also true that the fractional values thus introduced would not be directly referable to the ordinary computations of decimal arithmetic—thus adding, somewhat, to the complexity and trouble of otherwise very simple calculations; but this is a fault, not of the binary divisions themselves, but resulting from a radical and incurable defect in the decimal system. So long as we continue to count, to add, subtract, multiply, and divide by tens, so long must we submit to this inconvenience (undoubtedly a serious one) or we must choose the greater evil of abandoning all attempts at uniformity and consistency of system, and continue, as heretofore, to measure and to weigh by heterogeneous tables, while we perform the necessary operations of comparing, compounding, and distributing these values, by a method or ratio entirely dissimilar; entailing upon ourselves the waste of time, labor, and patience, consequent upon a petty scheme of eternal and superfluous reductions.*

This horn of the dilemma is that which has been accepted by the coinage commission of England, to which a reference has just been made. The eleventh resolution of the Commissioners' Report is: "That the advantages in calculation and account-keeping, anticipated from a decimal coinage, may, to a great extent, be obtained without any disturbance of our present coinage, by a more extensive adoption of the practice now in use at the National Debt Office, and in the principal assurance offices, viz., of reducing money to decimals, performing the required calculations in decimals, and then restoring the result to the present notation." With our experience of a decimal coinage (notwithstanding its imperfections), this is not the horn likely to be selected by Americans in attempting a reform in weights and measures.

An expedient has been suggested by some, for facilitating division in decimal notation, which is ingenious, and deserves a notice. The project is to adopt a uniformly decimal system of weights and measures, but to estimate entirely by "cents"—by simply suppressing every alternate denomination; thus, while reckoning decimally, we should traffic only centesimally. Our practical application of this method in all our money transactions, in which dimes are entirely suppressed in the market (though still having their place in the columns of the ledger) and our estimates made in *dollars* and *cents*, familiarizes our minds to the process, and enables us to see how such a system might be indefinitely extended, by the simple device of counting by double places of figures. The French table of weights would stand thus:

100 deci-milligrammes make .....1 centigramme.

*"Perhaps it may be found by more protracted and multiplied experience, that this is the only 'uniformity' attainable by a system of weights and measures for universal use; that the same material instruments shall be divisible decimally for calculations and accounts; but in any other manner suited to convenience in the shops and markets; that their appropriate legal denominations shall be used for computation, and the trivial names for actual weight or mensuration" (Adams's Report).

100 centigrammes	make	1 gramme.
100 grammes	"	1 hectogramme.
100 hectogrammes	"	1 myriagramme.

This suppression of the alternate denominations would have the advantage of abolishing the very objectionable terms *decigramme* and *decagramme*. Instead of the extreme awkwardness of taking one quarter of a gramme (2½ decigrammes), we are furnished with the value in whole units, by taking twenty-five centigrammes, just as we say twenty-five cents instead of two and a half dimes.

Simple and taking as this proposal is, it is not free from serious objections. It, in fact, complicates rather than simplifies, by giving a very wide range for estimating values. While it thus multiplies the units, and enlarges the interval between them tenfold, it only furnishes us with a single additional bisection, namely, the quartering. An eighth would still require a fractional expression. Its benefit, therefore, bears no proportion to the increased trouble and confusion involved. The necessity universally felt for quaternal and octaval divisions, would infallibly operate here as it has in our currency; and we should constantly hear of 37½ hundredths of a pound; 62½ hundredths of a pint, etc., which would be, in no respect, better than 3¾ tenths, or 6¼ tenths. The truth is, we need more frequent denominations than decimal ones, rather than more distant stepping-stones; and for some purposes, even the binary ratio of progression is not too slow. In looking over the various tables of weights and measures prevailing throughout Europe, it will be found that a large majority of the factors are 2, 4, and 8, with occasional resort to 3 and 6—the number 4 being, perhaps, the favorite number for the more customary denominations.*

Amid the conflicting claims of the numerous plans proposed for simplifying and uniting our incongruous metrology, there appears, at first sight, so much of irreconcilable contrariety, that it might be concluded that a combination of the respective advantages contemplated was hopeless and impossible; and that we were only left to a choice of evils. A more careful scrutiny will however discover a philosophy in these very discrepancies, and furnish the elements of a practical concord. On the one side, the convenience of a system of divisions or multiples conforming exactly to that by which we are compelled to perform all arithmetical operations, is so obvious, and so universally recognized,† that the advocates of an entire decimalization are certainly justified in their zeal. On the other hand, the necessity of binal progression and division, though not so generally ack-

* This is rendered very apparent on turning over the pages of Woolhouse's little work on the "Weights and Measures of all Nations." No. 101, of Weale's Rudimentary Series.

† "The great improvement of having but one arithmetical scale for reckoning integers and fractions of every kind, * * * is one so obvious, and, withal, so little difficult, that it is a matter of surprise that it should not have been attempted till near a thousand years after decimal arithmetic was first introduced into Europe" (*Edinburgh Review* for January, 1807, Vol. ix, page 373).

nowledged, is by all who have given the subject a careful study, so fully appreciated, as being, at least, as fundamental as that of the decimal scale, that those who urge the retention of all such denominations as are measured by the powers of 2, are no less justified. Which policy must, then, be sacrificed?

"The elementary principle of decimal arithmetic," says Mr. Adams, "is supplied by nature to man within himself, in the number of his fingers. Whatever standard of linear measure he may assume in order to measure the surface or the solid, it will be natural to him to stop in the process of addition, when he has counted the tale equal to that of his fingers. * * * But while decimal arithmetic, thus for the purposes of computation, shoots spontaneously from the nature of man and of things, it is not equally adapted to the numeration, the multiplication, or the division of material substances either in his own person, or in external nature. The proportions of the human body, and of its members, are in other than decimal numbers. The first unit of measures for the use of the hand is the cubit, or extent from the tip of the elbow to the end of the middle finger; the motives for choosing which are, that it presents more definite terminations at both ends, than any of the other superior limbs, and gives a measure easily handled and carried about the person. By doubling this measure, is given the *ell*, or arm, including the hand and half the width of the body, to the middle of the breast; and by doubling that, the *fathom*, or extent from the extremity of one middle finger to that of the other, with extended arms—an exact equivalent to the stature of man, or extension from the crown of the head to the sole of the foot. For subdivisions, and smaller measures, the *span* is found equal to half the cubit, the *palm* to one-third of the span, and the *finger* to one-fourth of the palm. The *cubit* is thus, for the mensuration of matter, naturally divided into 24 equal parts, with subdivisions of which, 2, 3, and 4, are the factors; while for the mensuration of distance, the foot will be found equal to one-fifth of the pace and one-sixth of the fathom" (*Adams's Report*).

"The fingers," says Dr. Lardner, "were naturally the first objects which presented to the mind the idea of number; and they furnished, also, a set of natural counters by which the number of things might be marked and expressed. The fingers, being continually in view, familiarized the mind with the contemplation of every number of objects not exceeding ten. It was natural, therefore, that ten should be adopted as the number of objects to form the first group. * * * Although ten has been so generally adopted as the *radix* of systems of numeration, as to leave no doubt of its origin, yet it is not the only one which has been used, nor is it the only radix having a natural origin. The fingers of one hand rendered the number five familiar to the mind, before the conception of ten as a distinct number presented itself. It was even more natural and obvious, that the fingers should be contemplated as

two groups of five, than as a single group of ten" (*Treatise on Arithmetic*, Book i, chap. i, p. 5-6).

The gradual and successive development of these scales, is so well set forth in Mr. Peacock's valuable treatise, that perhaps no apology is necessary for a somewhat lengthened extract from it, even at the cost of some repetition.

"The decimal scale of numeration is not the only one which may be properly characterized as a natural scale. In numbering with the fingers we might, very naturally, pause at the completion of the fingers on one hand; and registering this result by a counter, or by any other means, we might proceed over the fingers of the same hand again, or with the fingers of the second hand, and register the result by another counter, or replace the former by a new counter which should become the representative of ten. * * * Again, the scale of numeration by twenties has its foundation in nature, equally with the quinary and denary scales. In a rude state of society, before the discovery of other methods of numeration, men might avail themselves, for this purpose, not merely of the fingers on the hands, but likewise of the toes of the naked feet; such a practice would naturally lead to the formation of a *vicenary* scale of numeration, to which the denary, or the denary with the quinary, or the quinary alone, might be subordinate. * * * Of other systems of numeration, the binary might be considered as natural, from the use of the two hands in separating objects into pairs, and from the prevalence of binary combinations in the members of the human body; but the scale of its superior units increases too slowly to embrace within moderate limits the numbers which are required for the ordinary wants of life, even in the infancy of society. * * * As the necessity of numeration is one of the earliest and most urgent of those wants which are not essential to the support and protection of life, we might naturally expect that the discovery of expedients for that purpose should precede the epoch of civilization, and the full development and fixing of language. That such has been the case, we shall find very fully and clearly established, by an examination of the numerical words of different languages; for, without any exception which can be well authenticated, they have been formed upon regular principles, having reference to some one of those three systems which we have characterized as natural; the quinary scale, whenever any traces of it appear, being generally subordinate to the denary, and, in some cases, both the quinary and denary scales being subordinate to the vicenary. In some cases, also, we shall find, from an examination of primitive numerical words conveying traces of obsolete methods of numeration, that the quinary, and even the vicenary scales have been superseded altogether by the denary" (*Encyclopedia Metropolitana*, art. "Arithmetic," Vol. i, p. 371).

Decimal arithmetic thus appears to be coëval and coëxtensive with the human race. It is, indeed, perhaps, the most universal of human insti-

tutions—at least as universal as language itself. From this universality, most writers have called it the "natural" system; but on examining the question whether the number *ten* possesses any intrinsic excellence or convenience to recommend it—any peculiar fitness as a ratio of geometrical progression, we find but one answer—it has none. It differs from any other number only in quantity, not in quality. So far from its presenting any merit or advantage over its compeers, it is almost the last number which a true science of arithmetic would have selected for the important function of a radix of numeration. Its universality flows simply from the fact that the necessities of man impelled a selection, in the very earliest infancy of the race, long before the invention of letters, and while yet a language was but slowly being formed; and the selection comes to us stamped with the crude impress of a most irrelevant accident. Had the six-fingered giant slain by Jonathan (2 Samuel xxi, 20) lived early enough to be the father of the first unreasoning tribes, we should have had a duodecimal arithmetic; or if, like the fowls of the air, we had usually but four toes to our extremities, we should now have been able to calculate only octavally; and in either event we should have been much more skillful computers than we are at present. *

Decimal numeration is "natural" then, only in the sense that *ignorance* is natural. The fingers have no more real or "natural" relation to the properties of number, than have any other organs or divisions of the human body; and mathematically or philosophically considered, the *digit* is, therefore, no more a typical *unit* than a tooth (of which there are thirty-two), or the leg of a spider (of which there are eight), or the petal of a flower (of which there may be any number). Nor have any but the most ignorant races—those without a literature and an alphabet—ever occasion to group and tally by their fingers. Only from unlettered savages could such a scale, therefore, have deen derived.

It has been a favorite theory with a certain class of thinkers that primitive man was a highly civilized being—"a scholar and a gentleman;" and that the decay of states, and the decline of civilizations so unfortunately frequent in his history, but manifest his prevailing tendency to degeneration. Our universal arithmetic furnishes us with one of the most striking refutations of such a fancy. Wherever over the broad earth, the decimal scale exists, there have we the enduring monument of the ancestral savage—counting by his fingers or his naked toes.†

* "There can be no doubt that if man had been a twelve-fingered animal, we should now possess a more perfect system of numeration than we do. Whatever be the radix of the scale, it would always be a convenience to be able to subdivide it with facility, without resorting to the more refined expedient of fractional language" (*Lardner's Arithmetic*, chap. I, p. 21).

† The German word for ten—*zehen*—signifies "toes," being the plural of the word, *zehe*, We do not generally or readily recognize this intellectual association in our own language; and yet the Saxon word—*ta*—a "toe," is in the plural *tan*. The *daktul* (δακτυλος) of the Greeks, and the *digit* (digitus) of the Romans, which signified either "finger" or "toe," appear evidently affiliated to the *deka* (δεκα) of the one and the *decem* of the

Had any intelligent forethought ever presided over the inception of a numerical scale—had any comprehensive conception of the uses and purposes of figures, in any single instance guided the selection of a ratio for their multiplication—that ratio must inevitably have been something else than *ten;* the duplication of an odd number—incapable of any other division—neither a square, a cube, nor other power of any integer—and in its successions among the most inefficient for the expression of fractional values, or for the extraction of roots. And if among the patriarchs of the human family, a rational scale had ever been so devised, some traces of this wiser system must have been found, to give a "sign" and memento of man's pristine elevation.

"The number ten," remarks Mr. Anderson, in his treatise on Arithmetic, "has been adopted by every civilized nation for the radix of the numerical scale. It has no peculiar advantages to recommend it, and seems to have been selected for that important function, merely because it expresses the number of the human fingers. We must regret that a circumstance so totally unconnected with every scientific consideration, should have determined an elemental principle, of the last importance to one of the most abstract, as well as one of the most useful of all the sciences; and that the decimal notation should still be retained, notwithstanding its evident imperfections, and the superior claims of other scales" (*Edinburgh Encyclopedia;* edited by Sir David Brewster, art. "Arithmetic," Vol. ii, page 411).

An able and philosophical writer in the *Edinburgh Review* holds very similar language. "Ten has indeed," he observes, "no advantage as the radix of numerical computation; and has been raised to the dignity which it now holds, merely by the circumstance of its expressing the number of a man's fingers. They who regard science as the creature of pure reason, must feel somewhat indignant that a consideration so foreign and mechanical, should have determined the form and order of one of the most intellectual and abstract of all the sciences" (*Edinburgh Review,* for January, 1807, Vol. ix, page 376).

A large number (perhaps even a large majority) of the well-educated have been accustomed to regard the decimal system as possessing a peculiar beauty and expressiveness, from the great facility with which the ordinary operations of arithmetic are performed by it. Indeed, after laboring at the tedious and troublesome reductions of compound num-

other; although the genealogy (as in English) was probably more ancient than the languages themselves. So uniform are the laws of mind and matter, that we have only to select some rude and isolated tribe of modern savages to discover with a naturalist's confidence, the exact process of development in numeration, with the aborigines of our race, milleniums on milleniums ago. Klaproth, in speaking of the inhabitants of the peninsula of Kamtschatka, says: "It is very amusing to see them attempt to reckon above ten; for having reckoned the fingers of both hands, they clasp them together, which signifies ten; they then begin at their toes and count to twenty; after which they are quite confounded, and cry "Matcha," that is, where shall I take more?" (*Sprachatlas,* page 16.)

bers (consequent upon other scales of progression) unfortunately so often required to be made, the relief of a simple addition or multiplication in the homogeneous units of our common scale, is too striking not to excite a feeling of admiration for the easier process. It appears not to be generally considered, however, that this facility of computation is in no respect due to the series of "tens" by which we count, but is derived exclusively from the admirable notation in which the series has been clothed, and through which alone, we are in modern times made acquainted with it; and from the perfect conformity of the notation to the series. Any other scale will be found to exhibit an equal facility, if the same notation be employed, and made to correspond strictly with the selected scale. If, like the old Arabian philosophers, or like the ancient Greeks and Romans, we were compelled to calculate by a set of *alphabetic* numerals, we should be able to better realize how much we are indebted to that simple and yet grand invention of India, the "cypher figures," or the set of figures with the device of local value.* This system of numerical language presents us with a formula of geometrical progressions, so illimitable in range, and yet so perfect in its conciseness and distinctness, that it transcends all conception that the ingenuity of man in all coming time shall ever be able to improve it.

Though from a remote antiquity familiar to the Hindoos (that wonderful people from whom the civilized world has derived so much), it was wholly unknown to the nations of the earth until comparatively modern times; having been first introduced into Arabia, less than a thousand years ago, and from thence by slow and successive centuries into the various languages of Europe.

However much the Arabian philosopher to whom belongs the honor of having first transplanted the Sanscrit Arithmetic into his own country, may have been impressed with its great power and beauty, he could hardly have appreciated, to its full extent, the importance and magnitude of the gift he was instrumental in presenting to the civilized world; a transfer which Sir John Bowring in his "Decimal System" (chap. ii, p. 22) has characterized as "the greatest step ever made towards the introduction of a universal language among the nations of the world." The Hindoo numerals, from the channel of their introduction into Europe, were generally called the "Arabic figures"—a title they still commonly retain, though it is one hardly just to the people with whom these figures had their origin.

Now although this Hindoo notation has never been popularly applied to any other than the decimal scale, it is obviously a formula of universal applicability; and if made use of to express a system of figures with any other radix than *ten*, would give the same facility to all calculations performed by that system.

Abstracting, for a moment, all specific value from the terms "units," "tens," "hundreds," and "thousands," and regarding them merely as

* See note A, page 357.

symbols of *local value* (designating only the orders of units), we may exhibit in a tabular form, a series of scales, with the successive increments of value for each place, according to the radix, or ratio of geometrical progression selected. In the following table the letter "U" in the top line denotes a "unit;" that is, any figure which may occupy a single place:

TABLE OF ARITHMETICAL SCALES.

Hindoo Notat'n	U.	UO.	UOO.	UOOO.			
Scale.	Units.	Tens.	Hundreds	Thousands.	Radix	Logar'm	Places
Binary.....	1	2—	4—	8—	2	.301	$1\frac{0}{3}$
Ternary.....	1—2	3—	9—	27—	3	.477	$\frac{2}{1}\frac{2}{2}$
Quaternary	1—3	4—	16—	64—	4	.602	$\frac{1}{3}$
Quinary	1—4	5—	25—	125—	5	.699	$1\frac{0}{7}$
Senary.....	1—5	6—	36—	216—	6	.778	$\frac{1}{9}$
Septenary.....	1—6	7—	49—	343—	7	.845	$\frac{2}{1}\frac{0}{7}$
Octonary.....	1—7	8—	64—	512—	8	.903	$\frac{1}{9}\frac{0}{}$
Novenary.....	1—8	9—	81—	729—	9	.954	$\frac{2}{1}\frac{0}{9}$
Denary	1—9	10—	100—	1000—	10	1.000	1
Duodenary'.....	1—11	12—	144—	1728—	12	1.079	$\frac{2}{1}\frac{5}{1}$
Quaterdenary...	1—13	14—	196—	2744—	14	1.146	$\frac{1}{3}\frac{0}{7}$
Senidenary.....	1—15	16—	256—	4096—	16	1.204	$\frac{5}{6}$
Octonidenary...	1—17	18—	324—	5832—	18	1.255	$\frac{4}{5}$
Vicenary.....	1—19	20—	400—	8000—	20	1.301	$\frac{1}{1}\frac{0}{3}$
Tricenary.....	1—29	30—	900—	27000—	30	1.477	$\frac{2}{3}\frac{5}{7}$
Quadragenary..	1—39	40—	1600—	64000—	40	1.602	$\frac{5}{8}$
Quinquagenary.	1—49	50—	2500—	125000—	50	1.699	$\frac{1}{1}\frac{0}{7}$
Sexagenary	1—59	60—	3600—	216000—	60	1.778	$\frac{5}{8}\frac{0}{9}$

The number of places for each scale is inversely as the logarithm of the radix.

The most striking feature displayed by such a comparison of the different scales is the rapid increase of value in the higher ratios, as compared with the lower. While the *ternary* scale, for example, requires four figures to express so small a number as 27, the tricenary scale expresses one thousand times as many, by the use of no more places. The very first inquiry would, therefore, naturally be (in the absence of any other consideration), which would be found more convenient—a very small radix, or a very large one.

The first and lowest scale of the series—the *binary*—presents, with some disadvantages, many very remarkable advantages. In the first place it requires but a single figure, 1 (together with the cipher for determining its place), to express with facility and precision all the values within the reach of figures.* According to the law of the Hindoo notation, by

* It was in reference to this curious property of the scale, that a medal struck in honor of Leibnitz, and to commemorate his invention of the binary system, bore on its reverse, the striking inscription: "Omnibus ex nihilo ducendis sufficit Unum." Unity being very commonly regarded as the symbol of the Deity (*Peacock's Arithmetic*, Encyclopedia Metropolitana, Vol. ii, page 392).

which every zero multiplies all the value that precedes it, by the amount of the radix, it results that the addition of a cipher to the figure 1, would of course multiply it by two (instead of by ten as in our common system)—the addition of two ciphers, by two times two, or four (instead of by a hundred)—the addition of 3 ciphers, by eight; of 4 ciphers, by sixteen; of 5 ciphers, by thirty-two, etc. The first fifteen numbers would read thus: 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111.* The present year, 1887, would require eleven places of figures to express it; namely, 11101011111. Fifty places of figures (or 1 and 49 ciphers) in the binary system, would require but fifteen places of figures in the decimal system. One hundred places of the binary (1 and 99 ciphers) would require thirty places of the decimal. So that the former system would involve, on an average, the constant employment of about three and a third times more figures in all our arithmetical operations, than the latter system, or that in common use. This increased expenditure of time and manual labor would evidently be a very serious inconvenience. On the other hand it must be considered that the writing down of any given mass of figures, in only two characters (always either 1, or a cipher), would be much more easy and expeditious than if the mass consisted of ten different characters; so that the actual increase of trouble should be set down at probably not more than *double* that we have at present. This much quantitatively. But in the quality of the work done, the difference will be found immensely in favor of the binary scheme. In the first place no tables would be required to be committed to, and retained by, the memory; either of addition, of subtraction, of division or of multiplication; not even the fundamental "twice two make four." Every form of calculation would be resolved into simple numeration and notation. In fact, calculation as an effort of mathematical thought, might be said to be entirely dispensed with, and the labor of the brain to be all transferred to the eye and the hand. A perfect familiarity with the notation of the scale, and with the simple rules of position, would enable the operator to determine in every case by mere inspection whether the next figure should be a 1, or an 0. It follows that the only errors possible in such a work would be the merely clerical ones of the eye or hand; and when we reflect that a large majority of the arithmetical errors committed are usually those of the brain, fatigued or bewildered by the constant strain upon the attention and memory, this consideration of the increased accuracy of such a system is one of the very first importance in estimating its value. To many, the relief it proffers in exchanging head-work for hand-work will appear no trifling recommendation; and it may well be doubted, whether in all important and lengthy calculations, the binary system would not be found to afford a real economy of labor, instead of an increase as has been generally supposed.

It has been previously noticed, that the great Leibnitz, the rival of

* See note B, page 359.

Newton in the invention of the "Differential Calculus," proposed this system and zealously urged its adoption; although he thought that for more common purposes it would be found too prolix. "De Lagny took the trouble of constructing logarithms on the principles of this arithmetic, as being more natural than those usually employed. * * * He even proposed to substitute binary arithmetic for logarithms, affirming that it was more simple and expeditious, and conducted to the object in view in a less indirect manner" (*Anderson's Article on Arithmetic, in Brewster's Edinburgh Encyclopedia*, Vol. ii, pp. 376 and 409). The same writer adds that "Dangicourt has applied the binary notation with greater success to progressions, and proved that the laws of a series may be detected by it more easily than by any other scale." This results, it may be as well to state, from the fact that "circulating periods" of figures return far more frequently in this scale than in any other.

The *Ternary* scale, although it is also a very simple scale, has nothing else to recommend it; being incapable of integral bisection, and having very nearly the redundancy of the binary scale, without one of its advantages. It may be regarded as one of the most objectionable of all the scales; and indeed none of the odd numbers could, for a moment, be accepted as a suitable radix of notation.

The *Quaternary* scale, as derived from the second power of the binary scale, has many of its excellences. While it employs less than half the number of digits, of the common or denary scale, to task the memory and attention, it requires only about five places of figures, for three of the latter. It combines, therefore, great simplicity of structure, with a moderate range of notation, and would form a very convenient and practicable system of numeration; while it would furnish an admirable scale of division for weights and measures of all kinds. It is said by Balbi, that a very low and ignorant tribe of Indians in South America—the Guranos—had names for only four digits, and that after counting these a second time (to eight) they were unable to proceed any further. The correctness of this account appears, however, to be exceedingly doubtful. It is remarkable, too, that Aristotle mentions a tribe of Thrace as being unable to count beyond four—a statement equally incredible.

The *Quinary* scale, whose notation would require ten places for seven of the *denary*, has nothing to recommend it; and yet from the accident of man being afflicted with five fingers, it has generally formed the basis of the scale in common use, and traces of it are to be found in perhaps a majority of the nations of the earth. The numerals of Malay and Java were anciently, for the most part, quinary, in subordination to the vicenary grouping. A trace of this system is also seen among the ancient Greeks, in their word πεμπαζεσθαί (to count by fives); as it is among the Romans in their notation of numbers above 5, 15, etc. The Persian term for "five" is *pendja;* and *pentcha* signifies the expanded hand. Among the South Sea Islanders, the inhabitants of New Caledonia and the Hebrides, as well as the barbarous tribes of Northeastern Asia, the quinary

scale appears still to prevail. The central tribes of North America show also traces of this digital period; and they are frequent among the innumerable languages of Africa. Thus with the Jalloffs, the word for "five"—*juorom*—signifies the "hand." So with the Foulahs, the Jallonkas, the Fellups, etc. There are no examples, however, of the number five ever having been used as a true radix of notation; that is, as a direct ratio of continued progression; $5 - 5 \times 5$ (25); $- 5 \times 5 \times 5$ (125), etc. The quinary scale has seldom gone further than 20.

The *Senary* scale would require about seventeen places of figures for thirteen of the common scale; and its notation would therefore have about a one-third greater extent. Though not one of the most desirable scales, it would be much superior to the denary system. The simplification arising from the reduction of its digits, would much more than counterbalance the extension consequent on the increase of its places. Like the denary scale, it admits of but one bisection; but it possesses the great superiority of admitting at the same time of a trisection. No examples of this scale are to be met with; although it is said to have been at one time decreed in China, by the caprice of an Emperor, who had conceived some astrologic fancy for the number six.

The *Octonary* scale approaches very nearly to the common scale in its capability of expression, as it requires on an average but one-ninth more places of figures to represent any given amount; that is, ten places of this scale would be equivalent to nine places of the denary. Being derived from the third power of the binary scale, it possesses most of the advantages of that system; though not its admirable simplicity. Like the quaternary, it admits of continued bisection down to unity; and, of course, of indefinite bisection below 1, by the simple expedient of an inverted, or negative notation (as in decimal fractions). As a perfect cube, it has peculiar advantages both as a radix of numeration, and as a ratio of progression or of division for weights and measures; and in the latter respect particularly, there is, perhaps, no other number that would so well express the average range of a convenient metrical multiple.

The *Denary* scale* may be said to present a tolerably convenient mean between the prolixity of a very small radix, and the intricacy of a very large one; besides which, it possesses the immense advantage of a universal establishment. But beyond this, there is nothing to be said in its behalf. Intrinsically, it is one of the most imperfect and troublesome scales which could be selected. Still, the inconveniences of the system should be very serious and very apparent, and the claims of any rival scheme very unquestionable, to justify the advocacy of a change, which

* The name "Decimal," by which our present system of arithmetic is commonly designated, appears not to have a perfect propriety. The terms "Octaval," "Nonal," "Decimal," "Duodecimal," etc., are derived from the Roman "*ordinals*," and belong to the series Primal, Secundal, Tertial, Quartal, etc. The idea really involved is not that of relation to a *tenth*, but of a relation to a grouping *by tens*, and would require the term "denal" or "denary"—from the Roman "distributive" numerals, of which the terms "binary," "ternary," etc., commence the series.

would root up all our established forms and habits of calculation—which would destroy the accumulated products of centuries of industrious thought and toil—which would entail upon us generations of new labor to attain even the same standard of tabular detail, and statistical information, now possessed; and which, more than all, would wholly demolish, and perhaps hopelessly, that uniformity so essential to the language of scientific investigation, and so universally conceded to be one of the most important aims and results of every project of metrical or numerical improvement.

Upon this basis must the question of so radical a revolution rest. But if it is shown that uniformity in many other relations than those of simple number, and no less vital to the interests and welfare of the race than this boasted uniformity of figures, has constantly and irretrievably been sacrificed to this great idol—if it is established by the voice of all experience that neither national nor international standards of length, of weight, of area, of volume, or of value, of any single subject, in short, to which these figures can be usefully applied, have ever the slightest hope of obtaining a general authority under the dynasty of this "universal" power —then must it be dethroned, for very uniformity's sake, and a new dispensation introduced, developed from such principles, and invested with such attributes, that it may rationally be expected to gain at length a universal ascendancy, through the concurrent approval and adherence of all intelligent nations. For the attainment of a real uniformity, there seems no other process or alternative; and for such an attainment, no sacrifice of temporary convenience could be held to be too great. The faults of the denary system are too radical to be amended—too obnoxious to be endured. Sheltered by the inertia and conservatism of inveterate habit, it has been tolerated already much too long. The unskillful contrivance of an early age, it is all unsuited to the wants or uses of an adult manhood of the race.

The *Duodenary* scale has over the denary the advantage of allowing two bisections, and, at the same time, like the senary scale, of admitting of a trisection. Its variety of factors, 2, 3, 4, and 6, give it a much greater power of expressing fractional values than any scale below it, or immediately above it; and it has accordingly been always found a convenient and favorite number for metrical divisions. The acres, the feet, and the pounds of the Romans were all divided by 12; as are the foot, and the Troy pound, still with us. The signs of the Zodiac, the months of the year, and the hours of the day, have illustrated the number from the remotest antiquity. In the old French measures of length, not only the foot was divided into 12 inches, but the inch into 12 lines, and the line into 12 points. The "dozen," the "gross" or (12^2) and even the "great gross" (or 12^3) are widely used in trade at the present day for the package of a variety of articles. From the many acknowledged advantages of the duodenary scale, it has found frequent and warm advocates for its adoption as a system of numeration. In the necessity of

two additional integers, it would offer however a considerable increase of complexity and mental labor; while the economy of places in notation could scarcely be regarded as appreciable—25 of the duodenary being required for 27 of the denary. As compared with the octonary, it would require 5 places, where the latter would require 6; so that while its digits are more by fifty per cent, the excess of the other in places is only twenty per cent. But there are far more important considerations than these, which unfortunately oppose themselves to the adoption of this system, as the best substitute for the denary, notwithstanding its admitted features of superiority.

The most fatal objection to the radix 12, is that it permits only a single bisection beyond that given by the radix 10. The quality of continued divisibility, we regard as paramount to all others; not merely for the convenience of art and trade, universal as their requirements are, but even for many scientific purposes; and however valuable the property of a *varied* subdivision (as that furnished by the duodenary scale), experience has fully demonstrated, what is clearly seen by theory, that no aliquot parts can ever be as widely useful as the binal fractions. Another objection to the 12 scale, somewhat allied to this, is that the number is not a *power* of any integer—a point, as we shall discover, of no slight importance. In this respect, it may be remarked, the number nine (awkward and inconvenient as it undoubtedly would be as the basis of an arithmetic) would have several advantages over the number ten, and even over the number twelve. A third objection to the scale under consideration, which, though not so striking, is yet no less real: the radix is too large. On the simple score of size, there must be somewhere in the indefinite range of scales, a point where we should expect to find the most convenient medium between the inexpediences of opposing difficulties; and although this most advisable limit of magnitude may not admit of very precise determination, the question is one of too great consequence in the comparisons we are making, not to deserve a special attention.

The *Seni-denary* scale presents many excellent points, the number 16 being both a square, and a fourth power, and admitting of indefinite division by two. Its only disadvantage is the incommodious number of digits it would require; while its notation would yet economize only a single place of figures in every six places required by the denary scale.

The *Vicenary* scale furnishes no single point of merit which could recommend it to our acceptance, unless its divisibility by four should be regarded as giving it a superiority to the denary. With an exceedingly troublesome and unwieldy range of digits, it would reduce the extent of our common notation only from 13 to 10 places. Man was, however, unfortunately born with 20 extremities, or branches to his limbs, and hence traces of what may be designated a rudimentary vicenary scale, are to be met with among many nations, both ancient and modern. In ancient Phœnicia and Palmyra, the system of numbering by twenties, as far as

the hundred, prevailed; and from these nations it was derived by the Celtic languages, in all of which its remains are still found. Among the Scandinavians, also, is found a vicenary numeration. The Greenlanders, having counted fingers and toes in periods of five, designated the number 20 by the word *innuk*, which signifies a "man." If they have occasion to proceed higher, the expression for 40 is *innuk arlak*—"two men"—etc. A similar method existed among the Aztecs of ancient Mexico; as well as among the tribes of South America. The Teutonic races retain in their languages the traces of the ancient "score," and in parts of England, counting by scores, or twenties, is still quite usual. The translators of our Bible have frequently (though by no means uniformly) introduced this mode of enumeration. Thus we have "three-score and ten" (Ps. xc, 10)—"three-score and twelve" (Numb. xxxi, 38)—"three-score and fifteen" (Acts vii, 14)—"three-score and seventeen" (Judges viii, 14), etc., etc. The mode of numbering still in common use in France also exhibits a very remarkable retention of the antiquated vicenary system.*

This scale is not, as might be supposed, an extension of, and attempted improvement upon, the decimal system. On the contrary, it almost universally preceded it; and its employment belongs to the very earliest and rudest stage of barbarian society. It betrays a period of human intelligence, so destitute of all resource, that fingers and toes must all be pressed into service, to meet the common wants of number; and when these have been exhausted, there has been found among some tribes, no power of thought or word or symbol for aught beyond. It indicates a period long before a conception of any expedient for numerical expressions had dawned upon the savage brain; and hence there is no example of the vicenary scale having ever been extended even as far as to the second place of figures, or to 20 times 20; nor probably even beyond one hundred. It is evident that when the necessity for expressing larger numbers began to be felt, the cumbrous scale of added "toes," must soon be dropped, and the range restricted to the more manageable mechanism of the ten "fingers." And, accordingly, we find the imperfect vicenary to be always overlaid by the denary, with glimpses of the former still appearing through its supplanter.

The *Sexagenary* scale deserves notice only from its historical interest in having been from a very remote antiquity employed for particular purposes among the people from whom we derive our arithmetical notation—

* "The French nomenclature is for the most part purely decimal. The decimal system is observed from twenty (*vingt*) to sixty (*soixante*); here we find a vestige of an old vicenary scale. Seventy, instead of being *septante*, as the decimal system would require, is *soixante-dix* (sixty-ten); seventy-one, *soixante-onze*, (sixty-eleven); seventy-two, *soixante-douze* (sixty-twelve), etc. Eighty, instead of being *octante*, is *quatre-vingt*, or four twenties, and ninety is *quatre-vingt-dix* (four twenties ten); ninety-one, *quatre-vingt-onze* (four twenties eleven), etc. Thus twenty becomes the radix of the system from sixty to a hundred." (*Lardner's Arithmetic*, page 11.)

an employment which has been perpetuated throughout Europe and America, to the present, in the smaller divisions of time and of the circle. This scale is of course far too cumbrous in the range of its units to have ever had a true notation, or to be ever possible as an actual system, founded on its own radix. With its enormous complication of figures, it would still require about $\frac{9}{10}$ (or more than half) of the places of the common system to express its values. It has been found very useful, however, in its limited application, both from the rapidity of its progressions, and from the remarkably varied range of divisibility it permits. The number 60 is divisible by 2, by 3, by 4, by 5, by 6, by 10, by 12, by 15, by 20, and by 30; and has indeed the greatest number of aliquot parts of any number below 96.

Our "minutes" and "seconds" of the degree and of the hour have thus an Oriental origin. In India, however, from whence the scale was derived, these divisions, as applied to time, had not the same value as with us; as there the day itself was divided into 60 parts, called *guries* (hours of 24 minutes), each *gurie* into 60 parts, called *polls* (minutes of 24 of our seconds), and lastly each *poll* into 60 *mimiks*, or twinklings of an eye (four-tenths of a second). It is believed that this division of time is retained by the Hindoos to the present day. They also employ a period of 60 years, as we do the century.

In its astronomical application this scale has been found exceedingly useful. The properties of the circle require that it should frequently be divided into sixths, as well as into quarters; the sixth being, as is well known, the radial arc, or that whose chord is exactly equal to radius. The zodiacal or ecliptic circle of the heavens had, from the earliest antiquity, been divided into twelfths, a period representing approximately the movement of the sun during one lunation. As this comprised very nearly 30 days, the "sign" became naturally divided into 30 degrees; and this expresses so closely the arc of the earth's orbit described in one mean solar day, that when the earth is moving slowest (or at its aphelion), it falls but three minutes within one degree, and when it is moving fastest (or at its perihelion), it exceeds the degree by only a single minute. The radial arc of two "signs," or 60 degrees, suggested its own subdivisions. Hence was derived the table of 60 seconds to the minute, 60 minutes to the degree, and 60 degrees to the sextant—6 of these completing the circle. This system, answering so well the requirements of various division, was introduced from India into the Alexandrian school by the illustrious Ptolemy,* who did so much toward giving astronomy a scientific form. The sexagenary scale has never, however, been computed by any other than a denary radix. It must excite surprise, therefore, that the Hindoo notation of the scale was not also introduced by Ptolemy at the same

* Although the sexagesimal arithmetic is commonly ascribed to Ptolemy, it is probably an Eastern invention. The Indians, to this day, employ the sexagesimal division of time" (*Edinburgh Encyclopedia*, art. "Arithmetic").

time; and the world thus put in possession of this grand invention eight centuries earlier than it was by the Arabic importation.*

In our survey of the principal scales, from which alone a selection could be made for popular uses, we have found that there are certain incidental, but opposing advantages, incompatible with each other; and that no scale, therefore, could possibly furnish a maximum of every condition that might be thought desirable. Thus the binary scale affords so admirable a simplicity, beauty and facility, that it would have to be regarded the perfect system, if its redundant employment of figures (the necessary consequence of its simplicity), did not render it unsuited to the small and constant calculations required in the daily course of trade. On the other hand the manifold divisions permitted by the sexagenary scale give it convenient qualities, impossible to the lower scales; but here we find a complication so onerous that it would appall the most inveterate of calculating monomaniacs.

The conditions, however, that are really most essential to an arithmetical radix, are so few and precise, and their requirements so imperative, that there is little difficulty in deciding upon "the best possible scale of numeration." The first consideration would naturally have regard to the size of the radix, in order to assign certain limits within which our scale is to be found. To realize a maximum convenience, it must be neither too large, nor too small. We have seen that while the notation of places (and the consequent labor of transcription) diminishes very slowly with the ascending scales—the tax upon the mental faculties increases in a far more rapid ratio. The labor of mere *calculation*, which may be estimated at zero for the binary scale, advances materially, and in a compound ratio with every figure added to the radix. Were we then required to choose between any two scales—separated by a considerable interval, that is, between a very small one and a very large one (no other insuperable objection being supposed), we should adopt, unhesitatingly, the smaller one. The advantage imagined by some, of the great expressiveness of a rapid increase of value, is wholly illusory. It needs comparatively very few figures, in any case, to carry us not only beyond all true conceptions of

*The Greeks, like the Hebrews, Arabs, and all other nations excepting the Hindoos, employed an alphabetic numeral; and it is a somewhat curious circumstance that our modern character for the cipher was derived not from India or Arabia, but from Alexandria. The Hindoos indicated the cipher place by a simple dot (.), and the Arabians, in borrowing their system, did the same; until the sexagenary system, introduced by Ptolemy so many centuries before, supplied them with a new character. This philosopher, finding a frequent occasion to mark the absence of a particular denomination (as "no minutes," or "no seconds"), in order to avoid mistake employed the first vacant letter of the alphabet for that purpose. As the Greek numeral for 60 is the letter ξ, all those which followed would be useless for the sexagenary scale; hence the next letter, *o* (omicron), naturally became the empty counter. This notation became established by long habit among the astronomers of Alexandria, Constantinople, and Arabia; and finally crept into the Hindoo system of numerals. Thus to the accidental position of the Greek letter *omicron*, which happened to represent *seventy*, we are indebted for the present form of our modern cipher as a circle, instead of a decimal period.

magnitude, but beyond all rational requirement of any real calculations we can devise. There is, in the law of continued geometrical progression, even on its lowest scale, a power so overwhelming, that we feel we have no extra wonder or admiration left to spare, upon these "infinites of higher order," and confess to a predilection not to travel at such dizzying speed.

The world has had some centuries of experience in the denary arithmetic. We are all familiar with the laborious and tedious discipline by which its practice is acquired; and we are all conscious of the exertion of thought demanded to perform a lengthy operation in figures. When we consider the amount of time bestowed in training youth in this branch of learning (and yet the fact that not one-half so trained are really expert in calculation), we must record it as our deliberate conviction, that *the denal radix is too large*. We believe that a lower figure would give the true desideratum—the *minimum* of labor. Nay, as between the scale of ten and that of six, we incline to the opinion that the latter would be found the more convenient notation. Its labor, both of acquisition and of exercise, would certainly be far less than half, while its figures in use would be only about a third more. *A priori*, we might expect that a scale established in rude and inexperienced times (were it not that it was really determined by an arbitrary and extraneous circumstance) would be too large in its ratio of progression—rather than too small; and that a more enlightened age would find it convenient to reduce it; just as we have seen to occur with the vicenary and the denary scales, in their early history.

The second essential that should be demanded in a radix is that it must admit of indefinite bisection, or, in other words, that it must be found among the powers of two; namely, 4, 8, or 16. As 4 is probably too small, and 16 certainly too large, we have the octonary scale alone left to satisfy our most vital two conditions of a medium size, and a complete divisibility. The concurrence of these qualities in any one scale, and in that one alone, is sufficient to establish its claims against all competitors. There is but one scale which could have any pretensions to be considered a rival, or which would be likely to find intelligent advocates; and that is the duodenary. Much stress has been laid upon the number of its aliquot parts. That this quality is a highly useful one, we frankly acknowledge, but yet, as we maintain, not nearly so useful as that other quality this radix lacks, the facility of successful halving. The number 12 is not a power; the number 8 is a cube; an important advantage in several respects, but particularly in the application of this scale to a system of metrology, from the simple relations thereby established between the measures of length and those of volume—by which both weights and measures of capacity are determined. All that has been said on the subject of the denary being too large a scale, applies with much greater force against the duodenary. And, finally, we believe that a large majority of the mathematicians would give their vote unhesitatingly in favor of the octonary arithmetic. It appears to combine advantages of

the very first importance, and those impossible in any other scale. While perfectly adapted to the highest requirements of science, it is as exactly suited to the trivial wants and petty occasions of our daily life. It possesses a degree of simplicity the most attainable without a sensible increase of figuring. The simple suppression of the largest two digits of our common system (8 and 9) throughout every place of figures, would be found to reduce the working labor by at least one-half. In choosing between a radix of a second power (as 4), and one of a third power (as 8), the latter would for several reasons be preferred. It would undoubtedly be advantageous for it to be at the same time both a square and a cube. But unfortunately we can meet with no such favored number, until we reach the period 64. Our octonary radix is, therefore, beyond all comparison the "*best possible one*" for an arithmetical system.

After this somewhat tedious preparatory exposition, we now propose to briefly develop the scale of numeration thus selected; and to derive from it an ideal system of measures, based throughout upon the leading ideas of the French system; availing ourselves, as we believe, of every beauty and refinement offered by it, and avoiding every difficulty and defect inherent in it. Let us attempt to employ our proposed scale of number in the first place, by putting it in an intelligible form. Although we might readily discriminate between the octonary and the denary notation by the simple expedient of using a somewhat different type, of our common figures (suppressing the 8 and the 9), yet even with this device, the association of local value is so strong that it would not be easy to avoid confusion of idea in attempting to read and understand the unfamiliar conversion. It will be found much easier, therefore, to devise a set of characters for the octonary scale; which should be entirely distinct both from the letters of the alphabet, and from our ordinary figures. To assist us still more in reading them, these characters might be made significant symbols, by the number of lines employed in the construction of each, though this would be a matter of very little importance in a form of character that should be permanently adopted. The characters should all be simple; they should all have the same size, for the obvious convenience of typographic "dress;" and they should be so distinctive, that no one could easily be mistaken for another. Let us then represent *one* by L; *two* by C; *three* by E; *four* by F; *five* by P; *six* by G; and *seven* by B; the cipher having no intrinsic value, may very well continue to be still represented by O. Our eight *digits*, then (if we must still use so barbarian and unmathematical a designation),* would stand thus: OLCEFPGB.

In reading these octonary numbers, a distinctive name for each, as

* It has been sometimes remarked by advocates of the octonary arithmetic, that if our stupid ancestors had only used their thumbs as the counters of the digits, they would have found that they had but eight fingers, and we should then have had the octaval period—"founded in nature." It may be supposed from the preceding discussion of this subject, that we attach but little importance to such a consideration.

well as for the places occupied by them, would become even more necessary than a distinctive form. The terms "ten," "hundred," "thousand," especially, are too essentially decimal in their origin, and too ineffaceably stamped by usage in their significance, to permit their use in any novel application. The names, like the symbols, should be both as simple and as distinct as possible. The simplest name is a monosyllable, containing but one consonant and one vowel sound. Let this then be the rule of our numerical vocabulary. It will be convenient and even advisable to preserve a resemblance to the popular numerical language, that the analogy of structure may be the more apparent. The word one will naturally give us the French "un;" two will give us "du;" three will give us "the;" the consonant sound being really a simple one, although requiring two letters in our language. The word "tre" would have been better, as being very near the Latin tres, the Greek treis and the original Sanscrit tri;* but the double consonant excludes it under our rule.

* It is a matter of curious philological interest to trace the Sanscrit or ancient Indian parentage of all our modern European languages, especially in the names of the numerals. In this particular the different vocabularies of the numerous and wide-spread races,—of the Celtic, the Romaic, the Sclavonic and the Gothic, with its two great families of the Scandinavian and the Teutonic, appear only as dialects of each other. The names of the first ten numbers, in a few languages, are here selected, mainly from the Introduction to Bosworth's Anglo-Saxon Dictionary:

Sanscrit.	Persian.	Greek.	Roman.	Welsh.	Gothic.	German.	Saxon.	English.
Aika	*yika*	*eis, en*	*unus*	*un*	*ains*	*ein*	*an*	*one*
Dwau	*du*	*duo*	*duo*	*dau*	*tvai*	*zwei*	*twa*	*two*
Tri	*seh*	*treis*	*tres*	*tri*	*threis*	*drei*	*threo*	*three*
Chatur	*chehaur*	*tessares*	*quatuor*	*pedwar*	*fidvor*	*vier*	*feower*	*four*
Pancha	*pendj*	*pente*	*quinque*	*pump*	*fimf*	*fünf*	*ff*	*five*
Shash	*shesh*	*hex*	*sex*	*chwech*	*saihs*	*sechs*	*six*	*six*
Saptan	*heft*	*hepta*	*septem*	*saith*	*sibun*	*sieben*	*seofen*	*seven*
Ashta	*hesht*	*okto*	*octo*	*wyth*	*ahtan*	*acht*	*eahta*	*eight*
Navan	*nuh*	*ennea*	*novem*	*nan*	*niun*	*neun*	*negon*	*nine*
Dashan	*deh*	*deka*	*decem*	*deg*	*taihun*	*zehen*	*tyn*	*ten*

That these Sanscrit terms should have been so widely diffused, while yet no traces of the Hindoo arithmetical notation should ever have been found outside of India, would seem to show that this derivation was antecedent to the formation of a written language, or, at least, prior to the invention of the *cipher*. A nomenclature may be easily transmitted orally by tradition; a notation could be communicated and preserved only by records.

To the Sanscrit we are indebted for the denominations of our lowest two coins. From the Sanscrit *Sata* or *Shatum* (a hundred), through the Latin *centum*, we obtain our "cent;" and from the Sanscrit *Dasa or Dashan* (ten), through the Latin *decem* and the French *dieme* or *dime*, we obtain the name of our "ten-cent piece."

The word *four* will give us "fo;" but for five, in order to avoid a consonant recurrence, we shall have to resort to the original Sanscrit, *pancha*, which will give us "pa." Our *six* will give us "si" or "se;" but for our next number, as we can derive no satisfactory help from English or Latin, Greek or Sanscrit, we are driven to some arbitrary syllable. As seven is the last of our series, we may accept the single independent term with less reluctance; and that its sound may be as distinctively marked as possible, let us call it "ki."

Here, then, we have assigned for each of the numerals "a local habitation and a name."

L *Un*; C *Du*; G *The*; P *Fo*; P *Pu*; G *Se*; B *Ki*.

Our decades—twenty, thirty, forty— offer us the very suitable and simple suffix "ty" to designate our octades. Our hundred suggests the syllable "der" as a convenient designation of the third place of figures; and our thousand will give us "sen." And here we may improve upon our present mode of expressing "places" by employing these distinctive suffixes as independent nouns, significant of a particular order of units, without reference to any special or intrinsic value. Thus a simple unit would indicate any figure occupying the first place; a Ty would indicate any figure occupying the second place; a Der any figure occupying the third place, etc.

But mindful of that prudent law—"economy of means"—and not to burden our infant scheme with too great a load of unfamiliar nomenclature (always the greatest obstacle to the reception of any novel system), let us resort to combinations of these simple suffixes, instead of applying a new term to each new place of figures. By this means we shall be required to introduce new terms only at the successive and advancing powers of each great unit. Thus using "Ty" for the second place, and "Der" for the third place, we may very well employ the word "Ty-der" for the fourth place, "Sen" for the fifth place, "Ty-sen" for the sixth place, "Der-sen" for the seventh place, and "Ty-der-sen" for the eighth place. Here is a pause; and to do honor to the number *eight*, this should comprise one independent period of figures; to be followed by a new term, the analogue of our Million.* We cannot derive a convenient suffix, however, from this term; we shall therefore have to coin a new one. Let us call our great figure KALY. We have thus the progression: One "Ty" squared is one "Der;" one "Der" squared is one "Sen;" one "Sen" squared is one "Kaly," the intermediate places being expressed by the obvious compounds of these words. Or to illustrate the series proposed by our own decimal terms, it is as though having assigned eight places

*Our *Million*, the square of the Roman *Mille*, is a comparatively modern word; and useful as it is now universally esteemed, it appears on its first introduction to have met with but little favor. "Bishop Tonstall, who has discussed at great length the Latin nomenclature of numbers, speaks of the term *million* as in common use, but he rejects it as barbarous" (*Peacock's Arithmetic*).

PROC. AMER. PHILOS. SOC. XXIV. 126. 2P. PRINTED DEC. 5, 1887.

of figures instead of six for our million origin, we should reach it by this scale: Tens, hundreds, ten-hundreds, thousands, ten-thousands, hundred-thousands, ten-hundred-thousands, millions; the "ten-hundreds" and the "ten-hundred-thousands" being interpolated places.

Words manufactured to meet a new want have always a somewhat barbarous and uncouth sound, until familiarized by custom; and are usually received but slowly and with reluctance. Unless they can boast a pedigree and a history, they must expect from the world, like other parvenus, no very cordial greeting. From the habits of thought of a very large majority of mankind, it is found so much easier to use old words in a double sense, than to accept the precision of a new phraseology, that there is little doubt the octonary notation could be much more readily taught (except to children) by simply erasing the figures 8 and 9, from the common arithmetic. That it is more philosophical, however, to assign to everything its own appropriate name, can scarcely need a formal statement; and if the system now proposed have the high claims and merits we have represented, no apology is required for the attempt to clothe it in a fitting garb. We here present accordingly the numeration table, as resulting from the names we have just above suggested:

NUMERATION TABLE.

L, Un = 1	LL, Unty-un = 9	CL, Duty-un = 17	GL, Thety-un = 25
C, Du = 2	LC, Unty-du = 10	CC, Duty-du = 18	GC, Thety-du = 26
G, The = 3	LG, Unty-the = 11	CG, Duty-the = 19	GG, Thety-the = 27
F, Fo = 4	LF, Unty-fo = 12	CF, Duty-fo = 20	GF, Thety-fo = 28
P, Pa = 5	LP, Unty-pa = 13	CP, Duty-pa = 21	GP, Thety-pa = 29
S, Se = 6	LS, Unty-se = 14	CS, Duty-se = 22	GS, Thety-se = 30
K, Ki = 7	LK, Unty-ki = 15	CK, Duty-ki = 23	GK, Thety-ki = 31
LO, Unty = 8	CO, Duty = 16	GO, Thety = 24	FO, Foty = 32
FL, Foty-un = 33	PL, Paty-un = 41	SL, Sety-un = 49	KL, Kity-un = 57
FC, Foty-du = 34	PC, Paty-du = 42	SC, Sety-du = 50	KC, Kity-du = 58
FG, Foty-the = 35	PG, Paty-the = 43	SG, Sety-the = 51	KG, Kity-the = 59
FF, Foty-fo = 36	PF, Paty-fo = 44	SF, Sety-fo = 52	KF, Kity-fo = 60
FP, Foty-pa = 37	PP, Paty-pa = 45	SP, Sety-pa = 53	KP, Kity-pa = 61
FS, Foty-se = 38	PS, Paty-se = 46	SS, Sety-se = 54	KS, Kity-se = 62
FK, Foty-ki = 39	PK, Paty-ki = 47	SK, Sety-ki = 55	KK, Kity-ki = 63
FO, Paty = 40	SO, Sety = 48	KO, Kity = 56	LOO, Under = 64

It will be seen by this table that we have no peculiar word corresponding to the "ten" of the denary scale; and this is regarded as an

advantage, not only in being more systematic, but in giving greater precision of expression and idea. Instead of using the same word to indicate both a place, or local value (as the "ten-place") and a specific number, we are furnished with two distinct words—"Ty" designating the place and "Unty" specifying one in the ty-place, as "Duty" specifies two in the ty-place. All that is needed to carry out this system is to add a table of places.

NOTATION TABLE.

Units.	Ties.	Ders.	Tyders.	Sens.
L Un	L0 Unty	L00 Under	L000 Untyder	L,0000 Unsen
C Du	C0 Duty	C00 Duder	C000 Dutyder	C,0000 Dusen
6 The	60 Thety	600 Theder	6000 Thetyder	6,0000 Thesen
F Fo	F0 Foty	F00 Foder	F000 Fotyder	F,0000 Fosen
P Pa	P0 Paty	P00 Pader	P000 Patyder	P,0000 Pasen
S Se	S0 Sety	S00 Seder	S000 Setyder	S,0000 Sesen
K Ki	K0 Kity	K00 Kider	K000 Kityder	K,0000 Kisen

Tysens.	Dersens.	Tydersens.	Kalies.
L0,0000 Untysen	L00,0000 Undersen	L000,0000 Untydersen	L,0000,0000 Unkaly
C0,0000 Dutysen	C00,0000 Dudersen	C000,0000 Dutydersen	C,0000,0000 Dukaly
60,0000 Thetysen	600,0000 Thedersen	6000,0000 Thetydersen	6,0000,0000 Thekaly
F0,0000 Fotysen	F00,0000 Fodersen	F000,0000 Fotydersen	F,0000,0000 Fokaly
P0,0000 Patysen	P00,0000 Padersen	P000,0000 Patydersen	P,0000,0000 Pakaly
S0,0000 Setysen	S00,0000 Sedersen	S000,0000 Setydersen	S,0000,0000 Sekaly
K0,0000 Kitysen	K00,0000 Kidersen	K000,0000 Kitydersen	K,0000,0000 Kikaly

The Unkaly is the eighth (or untieth) power of Unty. Its value is 16,777216; and it requires but one more figure to express this large amount, than is required by the denary scale. A second place of figures is not lost by our new system—that is, its notation does not exceed that of the common system by two places, until the number 8589,934592 is reached; these 10 figures requiring 12 (namely L and eleven ciphers) in the octonary scale to represent their value. If this should appear surprising to any, it must be remembered, that although at 8, and at 64, an additional figure is required by the octonary system, yet after 10, and 100, the denary also requires this additional figure; and considering this, we shall find that the two scales are *equal* in the number of places occupied—from 1 to 7, inclusive—from 10 to 63, inclusive—from 100 to 511—from 1000 to 4095—from 10,000 to 32,767—from 100,000 to 262,143—from 1,000000 to 2,097151—from 10,000000 to 16,777215—from 100,000000 to

134,217727—and for the last overtaking, from 1000,000000 to 1073,741823. After this long-continued chase, the octonary scale at the next figure, or 1073,741824 (Under-Kaly) loses a place which is never regained. It may not be uninteresting to add, that this scale does not obtain an excess of *three* places until it reaches the enormous number of 9 trillions, 223372 billions, 036854 millions, 775808, these 19 figures being expressed by ⊔ and 21 ciphers. This amount diminished by a single unit, or by the last figure 8 being exchanged for a 7, is expressed in the octonary system by 21 *kis* (⊟) which would be an excess of only *two* places of figures.

Turning from this comparison of the relative powers of the two scales, to their relative simplicity, as exemplified by the octonary multiplication table, we shall find the contrast here as striking as was their parity on the other hand remarkable.

MULTIPLICATION TABLE.

	⊏	⊖	⊢	⊩	⊖	⊟
⊏	⊢					
⊖	⊖	⊔⊔				
⊢	⊔⊐	⊔⊢	⊏⊐			
⊩	⊔⊏	⊔⊟	⊏⊢	⊖⊔		
⊖	⊔⊢	⊏⊏	⊖⊐	⊖⊖	⊢⊢	
⊟	⊔⊖	⊏⊩	⊖⊢	⊢⊖	⊩⊏	⊖⊔

The mere inspection of this table is sufficient to show, that the time and labor of acquiring it would not be half that required for committing to memory our received form ; and this facility of acquisition would include almost a corresponding degree of readiness in its use. Figures, like furniture stored in the chambers of the brain, require a constant attention and arranging, to be kept in state for use ; and the amount of care and trouble unconsciously bestowed upon them, must be proportioned to the number of the pieces after which we have to look. It is no idle boast, therefore, to say that a child could be taught a thorough knowledge of the four great rules of arithmetic, and a ready skill in their practical applications, through the octonary system, in one-half the time required for obtaining an equal knowledge and skill by the common system. Nor is this simplification of arithmetical operations its only merit. The danger of error increases rapidly with the increasing complexity of the numeric

scale; and there is no doubt that our new system would ensure an increase of accuracy, at least equal to its ratio of simplicity. And if to this were added the facility which would result from constructing all our tables of weight and measure upon this scale (a scale so admirably suited to them)—and thereby entirely discarding the whole tedious and troublesome practice of "reduction," from our Arithmetic—the economy of time and labor would be something quite astounding.*

Our exposition of the subject of numeration has been so extended that neither time nor space will now permit us to illustrate the practical working of the arithmetical system here proposed. It is evident, however, that we are here equipped with a mechanism fully adequate to the resolution and expression of all arithmetical operations. Framed by a strict analogy with our present system, it affords us every facility and advantage that this can boast; and differing from it only in the number of its integers, it relieves us entirely from the difficulties and embarrassments which have ever been the opprobrium of our decimal scale. Merely to exhibit the form and method of our scheme, we may here indicate that the present year, "1887," would, in the octonary style be expressed ЄΡЄΒ—*Thety pader and thety-ki.* The diameter of the earth (7925 miles) would be expressed Ь,ΒЄΒΡ—*Unsen, Kity theder sety-pa;* or in feet (41,847,188) Ć,ЄΒΡΟ,ΡΒĆΡ— *Dukaly, thety kider patysen, foty seder duty-fo.*

We now proceed as rapidly as possible to the application of this improved numeration to the determination and distribution of a system of weights and measures. Of all the systems of metrology yet perfected, or even proposed, that of the French is, in the philosophical character of its standards, as well as in the ingenuity, simplicity and precision of its details, undoubtedly by far the most admirable and the most worthy of our imitation. "The French System," says Mr. Adams in the excellent Report on Weights and Measures from which we have already more than once had occasion to quote, "embraces all the great and important principles of uniformity which can be applied to weights and measures. *But that system is not yet complete; it is susceptible of many modifications and improvements.* Considered merely as a labor-saving machine, it is a new power offered to man incomparably greater than that which he has acquired by the new agency which he has given to steam. It is in design the greatest invention of human ingenuity since that of printing. But

* "It is impossible to estimate with any degree of accuracy," says Mr. Nichol, "the amount of labor annually thrown away by the nation at large, while persisting in performing the manifold computations necessary to its gigantic commerce and industry, by means of a series of tables so needlessly complicated and imperfect as those now in use. But the waste of time and loss of money must be something quite enormous, while every day it becomes greater and greater. Were the different denominations of weights, measures and money brought into harmony with the fundamental principle of our common arithmetic, it may be safely affirmed that the labor of commercial and professional calculations would be reduced much below one-half of what is now expended in this direction, while the risk of errors would be diminished in a still greater ratio" (*Encyclopedia of the Physical Sciences*, art. "Weights and Measures," page 778).

like that and every other useful and complicated invention, it could not be struck out perfect at a heat. Time and experience have already dictated many improvements of its mechanism. But all the radical principles of uniformity are in the machine. * * * *Uniformity* of weights and measures—permanent, universal uniformity, adapted to the nature of things, to the physical organization and to the moral improvement of man—would be a blessing of such transcendent magnitude, that if there existed upon earth a combination of power and will adequate to accomplish the result by the energy of a single act, the being who should exercise it would be among the greatest of benefactors of the human race. The glory of the first attempt belongs to France. France first surveyed the subject of weights and measures in all its extent and all its compass. France first beheld it as involving the interests, the comforts and the morals of all nations, and of all after ages. * * * In freely avowing the hope that the exalted purpose first conceived by France may be improved, perfected and ultimately adopted by the United States and all other nations, equal freedom has been indulged in pointing out the errors and imperfections of that system, which have attended its origin, progress and present condition."

Looking at the French *metre* simply as a practical material standard, the first criticism we would naturally have to make upon it, is that it gives us a measure most unfortunate in its size.

In selecting a standard of measure (without any reference to its ideal derivation) two considerations of very obvious and primitive notice impose a tolerably definite limit as to what should constitute the length of a useful, popular measuring rule. The first is that it should be conveniently portable,* if not in a pocket, at least in a satchel, or upon the thigh; the second is that when held by one hand in careful and precise position for taking or giving measures its two ends should each be distinctly within accurate view, and within easy reach of the free hand for minute marking without any constraint or effort of the body. These two conditions,

*"Perhaps for half the occasions which arise in the life of every individual for the use of a linear measure, the instrument to suit his purposes must be portable and fit to be carried in his pocket * * * For all the ordinary purposes of mensuration, excepting itinerary measure, the metre is too long a standard unit of nature. It was a unit most especially inconvenient as a substitute for the foot, a measure to which, with trifling variations of length, all the European nations and their descendants were accustomed. The foot-rule has a property very important to all the mechanical professions which have constant occasion for its use; it is light and easily portable about the person. The metre, very suitable for a staff, or for measuring any portion of the earth, has not the property of being portable about the person; and for all the professions concerned in ship or house building, and for all who have occasion to use mathematical instruments, it is quite unsuitable. It serves perfectly well as a substitute for the yard or ell, the fathom or perch, but not for the *foot*. This inconvenience, great in itself, is made irreparable when combined with the exclusive principle of decimal divisions. The union of the metre and of decimal arithmetic rejected all compromise with the foot. There was no legitimate extension of matter intermediate between the ell and the palm, between forty inches and four. This decimal despotism was found too arbitrary for endurance" (*Adams's Report on Weights and Measures*).

which would both be assigned on perhaps one-half the occasions of its familiar use, render it tolerably manifest that its length should be not less than twelve inches, and while certainly excluding the yardstick and the metre, would probably designate the carpenters' two-foot rule as reaching the maximum limit of practicable length. Both the French metre and our yardstick are very awkward and inconvenient standards, being too long for all ordinary purposes of mensuration, excepting itinerary measure, and as a popular standard utterly worthless except on the counter of the draper. Moreover, we would naturally select such a rule as we would measure our houses by, or the furniture within them; such a rule as the carpenter would cut off or lay off his boards by; such a rule as the mechanic could use in his workshop or the machinist handle in fitting his engines. Theoretically it matters little whether our unit of reference be the inch or the mile, but for the practical business of daily life it becomes a matter of the very highest importance that our unit of measure should be such a one as shall have the most convenient and universal application.

Two standards only have ever had a general use and currency—the *cubit* and the *foot*. Both derived from the human person, it is natural they should be found the most useful measures for the common wants of the person. The cubit may be said to be almost a natural standard; and it is the most ancient of measures, while it is still prevalent throughout the orient. Universal, or nearly so, throughout the nations of antiquity—it was the common measure of the Israelites, and is referred to in their earliest records. The ark is measured in cubits (Gen. vi, 15), and the height of the flood is in cubits. Goliath's height was six cubits and a span. The temple of Solomon is measured in cubits; and walls of cities are measured by the same (2 Kings xiv, 13). The foot appears to be a much later standard of measure. Introduced by the Greeks and Romans, it has prevailed in modern times wherever the Roman influence has been felt.

If the foot has been found a more manageable multiple of both the pace and the fathom or its half—the ell—than the cubit, we are disposed to regard the latter as the more beautiful and useful rule, and the more convenient unit of length. Certainly the occasions are not unfrequent, when we need the addition of a few inches to our foot-rule to measure common objects. At all events, in selecting a standard, adapted to the popular wants, it may be regarded as tolerably manifest that its length should not be less than a foot, and that it should not exceed two feet—the common carpenters' rule. The cubit is the mean between these extreme limits.

This consideration brings us to the derivation of the standard. "In all the proceedings," says Mr. Adams, "whether of learned and philosophical institutions, or of legislative bodies, relating to weights and measures within the last century, an immutable and invariable standard from nature, of linear measure, has been considered as the great desideratum for the basis of any system of metrology. It is one of the greatest merits

of the French system to have furnished such a standard for the benefit of all mankind. * * * In the establishment of the French system, the pendulum, as well as the meridian, has been measured; but the *standard* was, after a long deliberation, after a cool and impartial estimate of the comparative advantages and inconveniences of both, definitively assigned to the arc of the meridian, in departure from an original prepossession in favor of the pendulum." A writer in the *Edinburgh Review* for January, 1807, remarks: "Three different units fell under the consideration of these philosophers, to wit, the length of the pendulum, the quadrant of the meridian, and the quadrant of the equator. If the first of these was to be adopted, the commissioners were of opinion that the pendulum vibrating seconds in the parallel of 45 degrees deserved the preference, because it is the arithmetical mean between the like pendulums in all other latitudes. They observed, however, that the pendulum involves one element which is heterogeneous, to wit, time; and another which is arbitrary, to wit, the division of the day into 86,400 seconds. It seemed to them better that the unit of length should not depend on a quantity, of a kind different from itself, nor on anything that was arbitrarily assumed. The commissioners therefore were brought to deliberate between the quadrant of the equator, and the quadrant of the meridian; and they were determined to fix on the latter, because it is most accessible, and because it can be ascertained with the most precision" (*Edinburgh Review*, Vol. ix, p. 379).*

That this selection was wise at the time it was made, cannot be doubted. That it would be wiser now to select the equator, can, perhaps, be made equally evident. By the modern methods of electro-magnetic determination of longitude, an arc of the equator could now be ascertained with as much accuracy, as one of a meridian, and perhaps with even greater precision. A national, or what would be far nobler, an international commission, liberally endowed with every needed equipment, for measuring in South America, and in Africa, arcs of the equator—if possible entirely across either continent; and also (what would be very important) one through the opposite island Borneo—is an enterprise due to the enlightened spirit and scientific progress of the age, and would be one worthy of the united wisdom and resources of the three greatest nations of the world. The determination of the precise figure and dimensions of our globe—that fundamental problem of practical astronomy—is one of such transcendent importance, that no outlays should be regarded as injudicious or misapplied that would offer the prospect of even a slight improvement in the accuracy of our results.

The equator is, in the first place, undoubtedly the true girth and measure of the earth; and the circumference should always be understood to be this natural measure, unless otherwise specified. In the next place, the meridian not being a circle (owing to the polar flattening of the earth) no two degrees of its quadrant have exactly the same value; which renders the estimates of its degrees exceedingly awkward. According to the com-

* See note C, page 360.

putations of Mr. T. J. Cram (*Silliman's Journal of Science* for 1837, Vol. xxxi, page 230), one degree of latitude at the pole is equal to 69.39759375 miles, while one degree at the equator is only 68.70859375 miles—a difference of more than two-thirds of a mile! In addition to all this there is some reason for doubting whether different meridians are uniform in length and curvature. An arc of the meridian south of the equator, measured in 1752, by Lacaille (at the Cape of Good Hope) gave very unsatisfactory results.

But through the reductions of various eminent mathematicians we have now the equatorial circumference of the earth as well and accurately determined as any other measure of it. The two best and most recent determinations of the earth's equatorial diameter, are those of Bessel and Airy, who, by independent calculations, agree in the value 7925.6 miles, and differ only by 234 feet! Bessel making it 41,847,192 feet, and Airy, 41,847,426 feet. The mean of these results will give us 131,467,196 feet, as probably a very close measure of the earth's equator. We have every reason, therefore, for deducing our standard of measure from this line—the only true circle by which the earth is circumscribed; we have none for going back to the irregular meridian.

In no particular has the decimal principle of the French system proved so signal and utter a failure as in its application to the division of the circle. We have already noticed that the sixth part of the circle is one of its fundamental divisions—one which cannot be neglected for any theoretical advantage of adherence to system. We have seen, moreover, how admirably our present division of the quadrant into ninety parts or degrees answers all the various purposes required. In adding ten more degrees to the whole, so as to make an even hundred, the French philosophers sacrificed completely its primary and beautiful relations. The sextant no longer had a possible expression in the centesimal scale. A very brief experiment demonstrated what should have been clearly anticipated without it, that the new degrees were wholly impracticable. This part of the system was therefore speedily and universally abandoned,* and yet this was really a surrender of the very foundation of the metrical division.

The *metre* had been made the 10 millionth part of the quadrant, that the new degree might represent just 10 myriametres; but the abolition of this ideal degree left the myriametre (and with it of course the metre) a most inconsequential and unmeaning unit. So that now the kilometre no longer represents a minute, and the decametre a second, as was its original plan and purpose.

The selection of the meridian necessarily involved a reference to its natural fraction, the quadrant—the distance from pole to equator; but had

* "The new metrology of France, after trying it [the principle of decimal division] in its most universal theoretical application, has been compelled to renounce it for all the measures of astronomy, geography, navigation, time, the circle and the sphere; to modify it even for superficial and cubical linear measure, and to compound with vulgar fractions in the most ordinary and daily uses of all its weights and all its measures" (*Adams's Report*).

the equator been the standard chosen, inasmuch as it has no such natural measure, the sextant of it might just as properly have been made the starting unit as its quadrant. And this would have escaped the principal difficulty; for the sextant will easily supply us with a multiple of the quadrant, though the latter may not conversely so readily commensurate the former. Instructed by such distinguished failures, let us then start with the sextant of the equator as our prime unit of measure. We shall thus be able to select a final modulus or rule, mainly with reference to its most desirable length—no longer trammeled by the compounding of binary and ternary divisions. Ten million metres made the quadrant. Our octonary scale is also furnished with its grand unit (the eighth power of the octade), which for want of a better name we have christened *unkaly* (L,0000,-0000). The sextant of the equator is 21,911199⅛ feet, or 262,934392 inches. This divided octavally into *unkaly* parts, gives us the quotient, 15⅜ inches, *almost exactly our ideal measure!* Midway between the two great rival standards of olden time, the cubit and the foot, it seems the very compromise of differences, the harmonizer of conflicting systems, and supplies us with a "module" perfectly suited to every requirement of popular mensuration. It needs but the application of octonary multiples to complete a metrology simple and unexceptionable.

Before giving the table, however, it will be proper to suggest a slight modification in the divisions of the circle, as a subject controlling, to some extent, the details of our linear measures. Should the degree retain its present value as the 360th part of the circle, we should advocate strongly the employment of this unit of the equatorial circle, as the origin of our new standard of measure. Dividing the degree into *undersen* parts (L00,0000), we should have a module about one inch longer than that previously obtained, and somewhat nearer, therefore, to the ancient cubit. Its exact length would be 16.717 inches.

The number 60, however, approaches so near to the octonary *under* (64) that the temptation would be very strong to reduce degrees, minutes and seconds to the simplicity of the general notation, unless there appeared some strong reason for retaining the present sexagenary scale. But there is no special occasion for dividing small arcs into thirds or sixths, that gives this ancient and venerable system any advantage comparable to that we should have of adding up or subtracting degrees, minutes and seconds by a single operation, instead of resorting as now to reduction. On the contrary, the need of frequent binal division is here, as with other values, very apparent; and in this respect the number 60 is very defective, as it permits but two bisections. The mariners' compass affords us a good illustration of the convenience experienced in a continued bisection of angles.* There would therefore be a positive benefit in substituting

* The cardinal points dividing the circle into quarters—each quadrant is divided into halves or octants, each octant into halves and quarters called "rhumbs" or "points" (8 in the quadrant), and finally each of these points into halves and quarters; the rhumb or point being 11° 15′, and the quarter rhumb or point 2° 48′ 45″.

the number 64 for 60. This would interpolate 4 degrees into the sextant, or 6 degrees into the quadrant; making the right angle to be expressed by 96° instead of 90° as at present. This, then, is the table we should propose; in which, it will be seen, the present values of arc are not so altered as to disturb appreciably our long-established ideas of degree, minute and second.

DIVISIONS OF THE CIRCLE.

L00	(64)	tertials	make	1 second	=	0″.823974
L00	(64)	seconds	"	1 minute	=	52″.734375
L00	(64)	minutes	"	1 degree	=	$(\frac{1}{1\,6})$° or 56′15″
L00	(64)	degrees	"	1 sextant	=	60°
LF0	(96)	degrees	"	1 quadrant	=	90°
600	(192)	degrees	"	the semicircle	=	180°
600	(384)	degrees	"	the circle	=	360°

One obvious advantage of this scale, in addition to its simplification, would be to bring the azimuth compass into harmony with the mariners' compass, by giving them common measures. As the latter divides the quadrant into 8 "points" or "rhumbs," each of these would be LF° (12 degrees) instead of 11° 15′, as at present; and the quarter-point would be 6° (3 degrees) instead of 2° 48′ 45″.

The zodiac, or ecliptic circle, has from time immemorial been divided into 12 "signs." This would be found a very convenient unit to be applied to such arcs generally, as would also the smaller unit of its quarter, or L0°, the eighth part of the sextant. As there is no name for this, let us give it the name of "arc" (made technical and specific), a name not inappropriate, since it is about the smallest arc we can readily distinguish from a straight line. This would give us the following scale:

L0°	(8 degrees)	=	1 arc	=	7° 30′
F0°	or 4 arcs	=	1 sign	=	30°
60°	" 6 arcs	=	1 octant	=	45°
L00°	" 8 arcs or 2 signs	=	1 sextant	=	60°
LF0°	" 12 arcs or 3 signs	=	1 quadrant	=	90°

Should the above scheme of graduation for the circle be accepted, it

will give an admirable simplicity to our table of lengths, which without further preface is herewith subjoined :

TABLE OF LINEAR MEASURE.

		1 point	=	($\frac{1}{200}$ inch nearly)			0.0038 ins.
L0 (8) points	make	1 line	=	($\frac{1}{33}$ " ")			0.03 "
L0 (8) lines	"	1 dent	=	($\frac{1}{4}$ " ")			0.245 "
L0 (8) dents	"	1 digit	=	(2 inches ")			1.959 "
L0 (8) digits	"	1 MODULE	=	(15$\frac{2}{3}$ " ")		1 ft.	3.672 "
L0 (8) MODULES	"	1 rod	=		3 yds.	1 ft.	5.37 "
L0 (8) rods	"	1 chain	=		27 yds.	2 ft.	7. "
L0 (8) chains	"	1 furlong	=		222 yds.	2 ft.	8. "
L0 (8) furlongs	"	1 mile	=	1 mile,	23 yds.	0 ft.	5. "
L0 (8) miles	"	1 league	=	8 miles,	1 yds.	0 ft.	3. "
L0 (8) leagues	"	1 *degree*	=	64 miles,	1480 yds.	2 ft.	5. "
L0 (8) *degrees*	"	1 *arc*	=	518 miles,	1286 yds.	1 ft.	11. "
L0 (8) *arcs*	"	1 *sextant*	=	4,149 miles,	1493 yds.	0 ft.	4. "
B (6) *sextants*	"	the *circumference*	=	24,899 miles,	158 yds.	2 ft.	

The table of lengths proper terminates with the league ; the denominations following being those of arc. From the derivation of the standard, however, they coincide with precise measures, and are therefore properly included in the table.

The "point" gives a dimension about equal to that of a section of a human hair, or of a very fine grain of sand, and may be considered about the limit of visible magnitude. It is therefore a very suitable origin of linear value, while it is an equally appropriate point of departure for microscopic measurements. The "dent" and the "digit" would be convenient measures for small articles. While this new *metre* gives us one of the most convenient rules that can be devised, the "rod" furnishes us with a highly useful ten-and-a-half foot measuring pole, and eight times this measure gives us the best "chain." But the peculiar beauty of the new Module is, that it precisely corresponds with the *tertial* of the new degree. *Under* Modules make one second (the "chain"); *Under* seconds make one minute (the "mile"); *Under* minutes make one degree ; and *Under* degrees—the Sextant. Or, progressing by the successive squares—*Unty* Modules make the rod ; *Under* Modules make the chain ; *Unsen* Modules make the mile ; *Unkaly* Modules make the Sextant.

As referred to the French measures, we have for the value of our principal new denominations the following : the "line" = 0.77746 *millimetres;* the "dent" = 6.21975 *millimetres ;* the "digit" = 4.9758 *centimetres ;* the

"module" = 3.98064 *decimetres;* the "rod" = 3.18451 *metres;* the "chain" = 2.54761 *decametres;* the "furlong" = 2.03809 *hectometres;* the "mile" = 1.63047 *kilometres;* and the "league" = 1.30437 *myriametres.*

For those measures in most common use, that is for those clustering immediately around the Module, it would doubtless be found highly convenient to give denominations to the halves and quarters; and thus conform them to the universal popular tendency to binary divisions. We therefore propose the following supplementary table; not to be on any account incorporated with the preceding, nor in any respect to modify it; but to retain always its subordinate character.

2 dents	make 1 nail		0.48975	ins.
2 nails	" 1 inch		0.9795	"
2 inches	" 1 digit		1.959	"
2 digits	" 1 hand		3.918	"
2 hands	" 1 span		7.836	"
2 spans	" 1 Module		15.672	"
2 Modules	" 1 ell	2 ft.	7.344	"
2 ells	" 1 fathom	2 ft.	2.688	"
2 fathoms	" 1 rod	10 ft.	5.376	"

Our tables of area, or surface measure, would of course be derived directly from our linear measures, by the familiar law of squares.

TABLE OF SQUARE MEASURE.

LO (8) digits square,	or	LOO (64)	square digits,	make	1	square	Module:
LO (8) Modules	"	"	LOO (64)	"	Modules,	"	1	"	rod:
LO (8) rods	"	"	LOO (64)	"	rods,	"	1	"	chain:
LO (8) chains	"	"	LOO (64)	"	chains,	"	1	"	furlong:
LO (8) furlongs	"	"	LOO (64)	"	furlongs,	"	1	"	mile.

For popular purposes, however, it would be necessary, or convenient, to have more numerous denominations of area measure; and a less rapid progression than that of *unders,* given in the above merely geometrical

table of perfect squares. We therefore propose to insert intermediate values, so as to give our table the systematic or octonary form.

TABLE OF AREA—OR SURFACE MEASURE.

			Mile	Acres	Yards	Feet	Inches.
	1 sq. Module	=				1	101.615
ⳆO (8) square Modules, make	1 *lot*,	=			1	4	92.92
ⳆO (8) *lots*,	" 1 sq. rod,	=			12	1	23.364
ⳆO (8) square rods,	" 1 *plat*,	=			97	0	42.9
ⳆO (8) *plats*,	" 1 sq. chain,	=			776	2	55.3
ⳆO (8) square chains,	" 1 *acre*,	=		1	1370	1	10.42
ⳆO (8) *acres*,	" 1 sq. furlong,	=		10	1280	8	83.4
ⳆO (8) square furlongs,	" 1 *district*,	=		82	567	5	91.27
ⳆO (8) *districts*,	" 1 sq. mile,	=	1	16	4541	0	10.

The intermediate (alternate) denominations of this table are not *perfect squares;* hence it was thought more correct to assign terms to them indicative of their superficial character without the use of the prefix "square." We observe here one advantage that would result from the radix of numeration being a perfect square. The square root of 8 is 2.828427124; or $\sqrt{\text{ⳆO}} = \text{C.GPOⳆⳆBⳆFG}$; hence this value would represent in any given units, the side of a square equal to ⳆO (8) of the square units. Thus the side of a square "lot" would be C *Modules*, G *digits*, P *dents*, O *lines*, and Ⳇ *point*. The side of a square "plat" would be C *rods*, G *Modules*, P *digits*, O *dents*, Ⳇ *line*, and Ⳇ *point*. The side of a square "acre" would be C *chains*, G *rods*, P *Modules*, O *digits*, Ⳇ *dent*, Ⳇ *line*, and B *points*. And the side of a square "district" would be C *furlongs*, G *chains*, P *rods*, O *Modules*, Ⳇ *digit*, Ⳇ *dent*, B *lines*, and Ⳇ *point*. A very simple parallelogram is however afforded us, which gives with precision the dimensions of these respective areas. Thus a "district," as a land measure, is a rectangular space of ground, measuring two furlongs in one direction, and four furlongs in the other; an "acre" a similar space of ground measuring two chains in one direction by four chains in the other; a "plat," a space measuring two rods in one direction, by four rods in the other; and a "lot" is in like manner a surface of two Modules by four Modules. This table presents, therefore, the simplest ratios of superficial measure which could be devised; and would be found admirably adapted to every purpose of mensuration. For smaller surfaces, it is probable that the following supplementary table would prove a useful resort:

									Yards	Feet	Inches.
4	square	dents	make	1	square	nail	=				0.239858
4	"	nails	"	1	"	inch	=				0.959433
4	"	inches	"	1	"	digit	=				3.837735
4	"	digits	"	1	"	hand	=				15.350941
4	"	hands	"	1	"	span	=				61.403766
4	"	spans	"	1	"	Module	=			1	101.615
4	"	Modules	"	1	"	ell	=			6	118.460
4	"	ells	"	1	"	fathom	=		3	0	41.841
4	"	fathoms	"	1	"	rod	=		12	1	23.364

For measuring volume, we would naturally employ simply the cubes of the preceding denominations; while the contents of such cubic metres respectively, of distilled water at its maximum density, would as obviously furnish the measures of weight. Throughout these derivative tables, we propose to adopt the MODULE as the universal standard. In this respect our linear unit is very greatly superior to the *Metre*, which, from its inconvenient size, has been made practically a standard only of lengths. The *Are* (the unit of surface) is derived, not directly from the *Metre*, but from the *Decametre;* the *Litre* (the unit of capacity) is derived from the cube of the *Decimetre;* and lastly, the *Gramme* (the unit of weight) is derived from the cube of the *Centimetre*. The greater simplicity of our project is manifest in this contrast.

TABLE OF VOLUMES.

									Cubic Feet.	Cubic Inches.
				1	cubic	dent	=			0.01468
L0 (8)	cubic	dents	make	1	"	nail	=			0.11747
L0 (8)	"	nails	"	1	"	inch	=			0.93977
L0 (8)	"	inches	"	1	"	digit	=			7.51817
L0 (8)	"	digits	"	1	"	hand	=			60.14537
L0 (8)	"	hands	"	1	"	span	=			481.16296
L0 (8)	"	spans	"	1	"	MODULE	=		2.22760	
L0 (8)	"	MODULES	"	1	"	ell	=		17.82085	
L0 (8)	"	ells	"	1	"	fathom	=		142.56680	
L0 (8)	"	fathoms	"	1	"	rod	=		1140.53441	

This simple scale of volumes or bulks, derived directly from our smaller linear table, gives a good illustration of the great beauty and convenience flowing out of the employment of a radix of numeration which is a perfect cube. Each of the cubic measures of the above table has for the dimensions of its side two of the linear values above it.

The practical conveniences of simple and direct relations between lengths, weights, and measures of capacity are certainly too obvious and too great, to be lightly thrown away. Thus, where we are furnished with a measure, the root of whose cube is precisely a measuring rule in common use (one of the many advantages which result from an octonary scale of weights and measures), the benefit is by no means trivial; the farmer can always, without any calculation, make himself a cubical box (whether to supply, or to verify a measure) whose capacity shall be fully as accurate as the "bushel" he may purchase—even admitting that such a process may not have the precision that would satisfy the experimental philosopher. And this is a benefit which would attach equally to every unit of measurement in the scale. Whenever so radical a change is contemplated as the introduction of new divisions or denominations of measure, the importance of adopting at the same time the most useful or convenient standards that can be devised, is too eminent to justify a moment's hesitation in throwing aside everything that has not some intrinsic value to plead for its preservation.

TABLE OF DERIVATIVE MEASURES.

The cubic	dent	gives the	morsel	measure and the	carat	weight.
" "	nail	" "	ligule	" "	scrap	"
" "	inch	" "	cup	" "	semy	"
" "	digit	" "	gill	" "	unce	"
" "	hand	" "	quart	" "	libra	"
" "	span	" "	octa	" "	stone	"
" "	MODULE	" "	MODIUS	" "	PONDUS	"
" "	ell	" "	pipe	" "	ton	"
" "	fathom	" "	butt	" "	load	"
" "	rod	" "	hold	" "	keel	"

This table furnishes us with a complete system. It needs but a simple calculation to exhibit our weights and measures in full. Our measures of capacity with their respective values are as follows:

TABLE OF CAPACITY MEASURE.

						Galls.	Pts.	Oz.	Drs.	Minims.
				1 parvum	=					.488
LO	(8)	parvums	make	1 morsel	=					3.905
LO	(8)	morsels	"	1 ligule	=					31.244
LO	(8)	ligules	"	1 cup	=				4	9.955
LO	(8)	cups	"	1 gill	=			4	1	19.64
LO	(8)	gills	"	1 quart	=		2	1	2	37.
LO	(8)	quarts	"	1 octa	=	2	0	10	4	56.
LO	(8)	octas	"	1 MODIUS	=	16	5	4	7	35.
LO	(8)	MODIUSES	"	1 pipe	=	133	2	7	4	44.
LO	(8)	pipes	"	1 butt	=	1066	3	12	5	56.
LO	(8)	butts	"	1 hold	=	8531	6	5	7	28.

Our language is unfortunately but very poorly supplied with terms expressive of capacity; and as the existing names for the smaller liquid measures used by the apothecary ("fluid-drachm" and "fluid-ounce") are exceedingly objectionable, from their reference to the incongruous standard of weight, we are compelled to reject them, although we have no appropriate denominations to substitute. The word "morsel" is perhaps sufficiently indeterminate to answer the purpose; and the Roman *ligula*, a small measure of about a spoonful, supplies a convenient term, having the same recommendation. The "cup," which is equally indefinite, represents about a half-ounce. The *Modius* of the Romans was about the quarter of a bushel; the term has been selected as a suitable one for indicating a standard *measure*, and also as suggesting its dimension, as the cube of the Module. The circumstance that it is here applied to a much larger volume than it was originally is comparatively unimportant.

As referred to our common table of "dry measure," as it is called, the new "quart" is equal to 1.79 pints; the "octa" is equal to 7 quarts and one-third of a pint, or about one-twelfth less than a peck; the new "Modius" contains 3849.3 cubic inches, and is therefore equal to one bushel, 3 pecks, 1 quart and half a pint, or to very nearly 1¾ bushels, the U. S. bushel containing 2150.4 cubic inches; the new "pipe" is equal to 14 bushels, 1 peck, 2 quarts and half a pint, and the new "butt" is equal to 114 bushels, 2 pecks and 2 quarts.

In the French measures our "quart" is very nearly equal to the *litre*, being .9855 of a *litre*; our "octa" = 7.884 *litres*, and our "Modius" = 63 *litres*.

It may not be out of place to mention here (as exhibiting an interesting and very early anticipation of our octonary scale of measures in England)

that by the act of 51st Henry III (1266), it was declared that "8 pounds [of wheat] do make the gallon of wine, and 8 gallons of wine do make a London bushel, and 8 London bushels do make the quarter."

Our proposed system of weights forms but a corollary from the preceding table of capacity measures; a Modius of pure water forming the standard unit, which we therefore call our *Weight* or *Pondus*. Taking the value of the cubic inch of distilled water at maximum density at 252,745 grains (the weight adopted by Mr. Hassler for the U. S. standard), the Modius or cubic Module would weigh 972891.328 grains, or 138 pounds, 15 ounces, 329.22 grains avoirdupois. This will give us the following table:

TABLE OF WEIGHTS.

				Av. lbs.	Oz.	Grains.
		1 mite	=			0.464
L0 (8) mites	make	1 carat	=			3.711
L0 (8) carats	"	1 scrap	=			29.69
L0 (8) scraps	"	1 semy	=			237.52
L0 (8) semies	"	1 unce	=		4	150.178
L0 (8) unces	"	1 libra	=	2	2	326.42
L0 (8) libras	"	1 stone	=	17	5	423.91
L0 (8) stones	"	1 PONDUS	=	138	15	329.22
L0 (8) PONDUSES	"	1 ton	=	1111	14	8.76
L0 (8) tons	"	1 load	=	8895	0	70.08
L0 (8) loads	"	1 keel	=	71160	1	123.14

While the "Pondus" is the standard of determination, the "libra," as the unit of weight in most common use, would be the secondary or derivative standard. Since *Under* "libras" make the "Pondus," this corresponds to our present hundred-weight. The new "ton" is not quite half a ton, and the "load" is very nearly 4 tons.

The "keel" is one-half larger than the English keel (a weight used only for coal), which is equal to 21 tons 4 cwt., and of which twenty make a "ship load." Or the English keel is two-thirds of our "keel," as above given.

Estimated by the French weights, our "scrap" = 1.924 *grammes;* our

"semy" = 1.5393 *decagrammes;* our "unce" = 1.2314 *hectogrammes,* and our "libra" = .98514 kilogramme.

It would probably be found convenient to distribute the more popular or frequently used weights (those from the "scrap" to the "libra") upon the binary scale; but as the divisions of halves and quarters practically accomplish this, it seems hardly necessary to suggest a series of intermediate denominations.

In the new standard of length here proposed and developed, we believe that every excellence of the French standard has been carefully preserved, and all its imperfections as successfully avoided. Starting from the same general principles by which that was obtained, we have made no departure from the details of its derivation, not required by the plainest and soundest deductions of experience, philosophy and common sense. Does the French method propose an *aggravated* yard as a convenient unit, we show the superiority of the cubit. Does it (on good grounds at the time) select an elliptical meridian, as its origin of measure, we show still better grounds for preferring the equatorial circle. Does it look (almost necessarily) to the quadrant as a natural unit, we show the greater propriety of the sextant. Does it rest on a thoroughly decimal basis, we show the most cogent reasons for adopting an octonary distribution. Does it find a fitting divisor only in the seventh power of its decimal radix, we accidentally find it in a great arithmetical unit—the eighth power of the octade. Does it finally give as its finished product, an imperfect *Metre,* we offer for acceptance a perfect *Module.*

The system of metrology derived from this new standard has in it nothing that is arbitrarily assumed. Each part of it is dependent upon every other, and each part flows from each, by a logical and systematic necessity. The whole is thus a perfect unit, simple and complete—comprehending every relation of dimension and of weight, and adequate to every purpose of precision, the minutest as well as the grandest.

We have thus endeavored to unfold with as much conciseness as was compatible with a clear presentation of the subject, what is regarded as the best possible method of fulfilling all the varied and difficult conditions required in an acceptable system of weights and measures, as well as the most effectual means of promoting that great desideratum of international commerce, an ultimate uniformity of standards among the nations of the earth. The serious and radical defects of our existing systems have been briefly noticed, and from the experience thus acquired the essential and practical wants of the community have been incidentally pointed out. As the result of this investigation, it is believed that there is no other practicable solution of the problem; for the attainment of a real uniformity, there seems to be no other process or alternative. No disadvantage would follow the adoption of this plan, save that of the disturbance and confusion necessarily consequent upon every change, and which must form the price of every valuable reform.

If it be urged that the introduction of still another system of weights

and measures, and one having no common unit with either the French or the English system, would be only adding to the existing diversity of standards, instead of tending to that great scheme of uniformity so cherished by the philanthropist, we have to reply that, if the system proposed be really of all the best adapted to the needs not only of one, but of all nations, then is the prospect of a general uniformity most reasonably to be anticipated *from* its introduction. If neither the metrology of England (which is also ours), nor yet that of France, is ever likely to obtain a universal conquest, some better scheme alone remains to give us a hope of ultimate success. Such a scheme is here presented. Founded upon the simplest and yet most comprehensive basis, it contains nothing that could be regarded as in any respect peculiar to one locality or latitude, or more suitable for one nation than for any other. Encumbered by no abstruse nomenclature, it aims at no superfluous verbal uniformity, but leaves each people to employ such designations of its units as may appear to each most easy and familiar.

Mr. Adams, after his unequaled analysis of the English system of measures, in view of its close agreement with our own, discountenances all attempts at a premature innovation. Without approving in his report of the introduction of the French system, he thinks it would afford the best prospect of securing "uniformity;" and remarks, "were it even possible to construct another system on different principles, but embracing in equal degree all the great elements of uniformity, it would still be a system of diversity with regard to France, and all the followers of her system. And as she could not be expected to abandon that which she has established at so much expense, and with so much difficulty, for another possessing, if equal, no greater advantages, there would still be two rival systems with more desperate chances for the triumph of uniformity."

On the contrary, it is believed, that provided a new system could be framed, which *had* demonstrably "greater advantages" than her own, France would be among the first of nations to hail its advent and to welcome its adoption. A nation to which belongs the honor and the glory of having been the first to invite the fraternal co-operation of other powers, and the first to work out with unwearied science, skill and labor, a comprehensive organization of that ideal metrology—unrivaled in its philosophy and symmetry—cannot be the last to appreciate any real improvement of that economy; or to submit to any sacrifice which should promote the realization of such improvement. Nor could the entire abandonment of that which has cost so much be accounted too great a sacrifice, if only through it could be accomplished that magnanimous design to which it owed its origin. It would have to be looked upon as a costly but invaluable experiment—as a great and necessary progression to an end, by which alone was rendered possible any higher attainment. The system here elaborated is but a development of *that*.

A project which contemplates the entire subversion of the existing

arithmetic, with its immense stores of fact and formula, is certainly a most startling proposal; and is one which will doubtless be regarded by the majority of persons as a scheme chimerical and impossible. We are impressed with a calm conviction that it does not even offer any real difficulty. The enormous labor of reconstruction involved, we seek not to deny or to underrate. But this is a trouble which must always be commensurate with the greatness of the reformation. This necessity would, however, most probably stimulate to the development and perfection of that most useful ally, the calculating machine. Rendered simpler in its construction by the very system which should require its services, and made popular and general by the new demand, it seems not improbable that a single century of the octonary empire would place the world on a higher platform than it would even reach without it. Such has been the usual history of difficulty and of success. A national government has but to *will* it to ensure its establishment; and after the first impediments of custom were surmounted, we nothing doubt, that the facility and manifold conveniences of the new *regime* would form its most powerful support, and its surest recommendation to popular favor.

If the octonary system have the germ of vitality, here imagined, its adoption by any one of the great nations of Christendom would as surely pave the way to its universal prevalence, as did the introduction of the Hindoo notation, and of the Gregorian calendar. Nor are the obstacles which so long delayed those great reforms, either as numerous or as serious at the present day, as they were in by-gone centuries. The tone and temper of the times—intellectual, moral, and political—differ widely from those of our ancestors; and in our common school system we have a moral mechanism for the inoculation of new truth, untried and unknown in all past ages.* Whenever the octonary numeration should be definitely established by political authority, we would immediately have all young children instructed for a year or two, only in the octonary arithmetic—as furnishing the easiest and most rational introduction to the knowledge of figures. And not until after a complete mastery of this arithmetic should they be taught the use of decimals—still required for a considerable period to enable reductions to be made from the old style to the new. This would be attended with no more labor than is the additional study now of ordinary Algebra; while in the distinctive languages of the two scales would be found a safeguard against all danger or difficulty, in confounding the one value with the other.

* In the interesting report made to the Secretary of the Treasury, Dec. 30, 1856, by Prof. Bache, Superintendent of Weights and Measures, it is well remarked in relation to the facility of introducing a decimal system, that "One generation would nearly suffice to effect this change, if, as in Holland, the new weights and measures were introduced through the schools. The children of the country becoming familiar with them in the primary schools, seeing the actual material standards of length, capacity and weight at frequent and stated times in early youth, and retaining that familiarity as they passed into the higher schools, would be readily prepared for their universal use when reaching mature life."

The economy of time and labor which the system of octonary computation would infuse throughout the myriad commercial details daily entering into the life of a busy and enterprising people, cannot be estimated, and could not easily be exaggerated. The popular wonder would be no smaller under the daily workings of this wiser system, that decimals could have prevailed so many centuries—than is our wonder now that the demands of trade could possibly have been satisfied by the awkward and complex Roman scale of numeration.

The objections naturally brought against any disturbance of the existing order of accountancy (backed on the other hand by the indolent and dilatory plea that we and our ancestors from earliest time have found it to answer quite "well enough") are precisely those which have uniformly opposed and retarded the introduction of every improvement. We are informed by Sir John Bowring, in his interesting sketch of the Exchequer system of England, that in quite recent times, Lord Granville strongly resisted the abolition of the Latin phraseology, and the substitution of the Hindoo numerals for the Roman, in the keeping of the public accounts, on the ground that the continuance of the accustomed system was necessary to preserve the comprehension of preceding records!*

The only question upon the subject that can be acknowledged as worthy of discussion, is that which regards the beneficial character of the revolution. "Is, or is not, the change proposed a real improvement?" If it be—if it be not only an improvement, but of all projected schemes the best—then we assert the bolder logic—*its adoption is only a question of time!* Prejudice, timidity or indolence, insensibility to the interest of the future, or superstitious reverence for the gray-haired follies of the past, may each or all oppose their ineffectual resistance; they may indeed postpone for a century or two the benefit to be enjoyed; they may indeed throw in the scale the added labor of accumulated work to be undone, but what is "best" shall surely, in the end, secure its empire.

To the objection urged by some that the advantages to result are too remote, and that even were the new arithmetic now inaugurated, the present generation could not expect to have the full and peaceful enjoyment of its alleged conveniences, we would reply that such has been the case with every really great reform. The rewards of far-reaching benefactions are never for the present. We are in possession now of many

* "It is indeed scarcely credible, that the perplexing and entangled manner of keeping accounts by the Roman numerals in the same barbarous style which was practiced before the Norman Conquest, was maintained at the Exchequer almost down to the present day; and the introduction of the English language and the Arabic numerals was successfully resisted by no less a personage than Lord Granville, on the ground that if the barbarous usages of our ancestors were reformed, it would be difficult to understand the accounts, and the records of departed time; and hence he argued for the necessity of perpetuating a system of complication, confusion and imperfection, not on the common plea of the superior wisdom of our ancestors, but in full acknowledgment and appreciation of the ignorance of the custom which was originally instituted, and which had continued to reign triumphant among the Exchequer records" (*Bowring's Decimal System, Chap. vii, page* 124).

priceless blessings whose first and feeble preparations were planned in former, unenjoying ages. Shall we reap the rich fruits grown from the unselfish providence of ancestral culture, and shall posterity be less favored? Patriotism and humanity reject the doubt. The octonary algorithm is pregnant with such great and widespread benefits—benefits to extend throughout all coming time, that its acquisition should be estimated as cheaply purchased by whole generations of transitional confusion.

The measure thus imperfectly advocated is by no means a new one. It is an incident of the highest interest and moment in the reign of that distinguished monarch, Charles XII of Sweden, that he not only contemplated the introduction of an octonary arithmetic, but that he commissioned Swedenborg (at that time celebrated for his scientific and mathematical attainments) to draw up the necessary details of the plan for establishing this system, together with an octonary scale of weights, measures and coins throughout his kingdom.* It appears that the premature death of the king very shortly afterward, alone prevented the consummation of this most sagacious and philosophic enterprise. But for this untoward circumstance this admirable mechanism would have thus been put into practical operation more than a century and a half ago! Had it proved as successful as there is every reason to suppose it would, who can estimate the influence this engrafting would have had upon the present mathematical condition of Europe? Might we not now have been in the full and assured enjoyment of that happier system? The subject of this improved numerical notation had doubtless often occupied the minds of mathematicians long before this time, but this is probably the first occasion on which a deliberate and well-designed attempt was ever made to give it a practical existence and establishment. As such it is an event of no trivial importance, and must be regarded as ever memorable in the history of arithmetical reform.

In contemplating the practical working of this untried system, and forming an estimate of the character of the change required in the popular habits of thought, comparison and judgment, there can be no doubt that the octonary scale could be generally introduced with far greater facility, and made thoroughly familiar in a much shorter time, in its application to the divisions of money, weight and measure, than it could be in its more abstract application to the operations of universal numeration; that in advance of the arithmetical reformation, it would be found highly expedient to introduce the simple and convenient system of weights and measures here proposed, as the best preparation for the successful introduction of the other.

Even were the octonary arithmetic (with all its own intrinsic excellences) not to be adopted, we still urge that these measures would be worthy of an independent establishment. After the variety of arithmetical reductions to which we are now accustomed under our present incongruous

*See note D, page 364.

tables, the uniform reduction of a single scale, which would alone be required in the new order, would give a very great simplification and relief, and would in every probability be found upon the whole to entail less inconvenience than that which would remain, with even the perfect decimalization of our various measures. So that even under the disadvantages of a decimal dispensation there can be little doubt it could easily be shown that our new system would still, in view of all the circumstances, be the "best possible" one for popular use, and would most completely furnish the elements of a perfect uniformity.

The system in use in this country has three units: The Yard, consisting of 36 inches; the Troy pound, consisting of 5760 grains, and the Wine gallon, containing 231 cubic inches; these units being entirely independent of each other. Upon these units our various tables of weights and measures have been constructed without regard to regularity or fitness for the practical purposes to which they must be applied, or without any approach whatever to uniformity or similarity in the various multiples or divisions of the units.

Any comprehensive and strictly philosophical system, as before stated, can have but one unit, which must give law throughout. That unit will most naturally be a linear measure, and whatever its derivation, where a change is made, "the coincidences between the old and new ratios will necessarily be rare. The best that can be done is to choose such a unit as will produce the most of these."

In consideration of the strong desire of very many persons to retain our present units, or at least the unit of measure, it is believed that the adoption, as our standard, of the English *inch* or multiple of it, the inch being the thirty-sixth part of the standard yard, which is also our standard yard, with an octonary distribution of the various tables of weights, measures and coins, although less philosophical and scientific than the plan just proposed, would be much more readily accomplished. This would leave undisturbed all linear measures of Great Britain and of the United States, and would possess all the essential elements for a successful adoption by both countries.

A specified number of inches might be taken as the standard, and from this all other measures, including those of surface, capacity and weight, derived; or if it should be considered preferable to retain the grain weight instead of the linear unit, the side of a cube containing a weight of water equal to a specific number of grains, might be taken as the standard.

The grain is a standard so widely used, and in medicine especially is one of so great value as the exponent of so much knowledge and experience, that it should not be lightly set aside, and its surrender is a sacrifice which ought to be compensated by very undoubted advantages. So far as medicine and pharmacy are concerned, it would seem to be the most important unit to be preserved. Not only is it at present the recognized measure of the physician and pharmacist throughout a great portion of Europe, that in which chiefly is embodied the long acquired

experience and accumulated knowledge of the healing art, the laboriously ascertained and accurately observed relations and values of all the more active portion of the Materia Medica, but it is the measure which, outside of the medical and pharmaceutical professions, is the one almost universally employed as the unit of comparison for all minute investigations and precise determinations.

If either one should be adopted, the other would have to be abandoned; and upon a careful consideration, notwithstanding the great importance of the *grain*, it is believed that the inch would be retained with less disturbance and with much greater advantage than the grain. Should the metric system be adopted, both the inch and the grain must be discarded.

Within a few years past various schemes have been proposed for promoting uniformity, but unless some one of them could be universally adopted, the confusion and complication would be increased instead of being diminished.

Prof. Oscar Oldberg has proposed for adoption by pharmacists and physicians, a new system based upon the "*Gramme*;"* he proposes to divide the gramme into sixteen parts called "grains," thus making a new grain, a little smaller than our present grain; four grammes to make a drachm, 8 drachms to make an ounce, and 16 ounces to make a pound; the pound would thus consist of 8192 new grains, or about 7900 troy grains.

Even if this scheme should be adopted universally by pharmacists and physicians, which does not appear probable, it would but increase the difficulties under which we are now laboring; it would only add one more to our already long list of tables of weights and measures to be learned.

There is no good reason why pharmacists or jewelers, or any other class of individuals, should have a special scale of weights and measures; many of the evils experienced by them are those prevailing in all departments, and no improvements or reform can be either efficient or enduring which do not look to the welfare of the whole. It will be found impossible to give exclusive and confined attention to the weights and measures of any one profession; there is absolute necessity of conformity among all the measures of trade and commerce, and of the reference of all to common laws and to a single standard.

These remarks will also apply to the scheme proposed by Mr. Wm. L. Turner for the use of pharmacists, published in the Proceedings of the Pennsylvania Pharmaceutical Association, 1886.

Mr. Turner proposes to divide the "*Gramme*" into 15 parts called "grains;" to make the ounce equal to 500 of these grains, and the pound equal to 14 ounces, or equal to about 7200 troy grains.

Before attempting any change it should be well considered whether we have attained all the benefit within our reach, or whether at no greater cost we might not reap the advantages of a far more perfect system.

*Manual of Weights and Measures. By Oscar Oldberg, Pharm. D. Second edition. Chicago, 1887.

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We would therefore propose to select for our "Module" a 16-inch rule instead of one of 15.672 inches, as suggested on page 338; all the tables as before given would remain unchanged in regard to their divisions and proportions, but of course the values would be slightly modified.

The Table of Measures of Capacity, and Weights, on page 355, shows the divisions and multiples of the "Modius" based upon this 16-inch Module, with their equivalents in Apothecaries' or Wine measure, and in cubic inches; also the divisions and multiples of the "Pondus," with their corresponding Avoirdupois weights, and the connection between the measures and weights.

A great beauty resulting from the use of a cube number for a metrical radix, with octaval divisions, is shown by this table. It will be observed that the Modius and all of its multiples and divisions are *perfect cubes;* and each one has a precise linear standard for the side of its cube; thus, the Modius is the cube of the Module (or 16 inches); the Octa is the cube of 4 digits (or 8 inches); the Quart is the cube of 2 digits (or 4 inches); the Gill is the cube of 1 digit (or 2 inches); and so it is with every ascending or descending measure of capacity; and the weight of the contents of these measures gives us a precisely corresponding series of weights.

To illustrate the contrasted awkwardness and complexity of a decimal system of measures, let the French "*Litre*" be selected. The *Litre* is the cube of the *decimetre*. Ten *litres* make one *dekalitre*, and if we would seek the cubic measure of this quantity, we shall find by a troublesome process of extracting the cube root, that 2 decimetres, 1 centimetre, 5 millimetres, and a decimal fraction .44347, and so on interminably, will give us an approximation to the length of the side, within an assignable limit of error. In other words, although there certainly is a cubic vessel, that shall contain exactly 10 *litres*, it is not within man's art of mensuration to tell precisely what the size of that cube must be. If, on the other hand, it were required to find the dimensions of a vessel holding exactly 8 *litres*, we know that a cube of 2 *decimetres* will give the measure with absolute precision; or, if on the descending scale, it were required to find the size of a vessel holding exactly one-eighth of a *litre*, the cube of 5 *centimetres* gives us the perfect solution.

By the simple device of using multiples of one, two, and four times the size of such of these weights or measures as may be desirable, the use of fractions is entirely avoided, and a perfect system of weights and measures is supplied, by which any conceivable amount can be easily and accurately weighed or measured. Another beauty in our system is that it gives a maximum range of expression with the minimum number of pieces.

Of the weights in our table, those in ordinary use by the pharmacist, jeweler, etc., would be the *mite*, the *carat*, the *scrap*, the *semy*, and the *unce*. Weights of once, twice, and four times the quantity of each of these, or in all 15 weights, would enable us to weigh any possible quantity of *mites*, from one (which is less than half a grain) to 16170 grains; that is to say, we could weigh 32760 different quantities; these 15 weights

Table of Measures of Capacity, and Weights.

Measures.		Wine Measure. Galls.	Pts.	Oz.	Drs.	Minims.	Cubes.	Cub. Inches.	Weights.	Avoirdupois. Pounds	Oz.	Grains.
	1 Parvum					.519	$\frac{1}{8}$ ins.	$\frac{1}{512}$	1 Mite			.4936
8 Parvums	1 Morsel					4.15	$\frac{1}{4}$ "	$\frac{1}{64}$	1 Carat			3.949
8 Morsels	1 Ligule					33.2	$\frac{1}{2}$ "	$\frac{1}{8}$	1 Scrap			31.593
8 Ligules	1 Cup				4	26.	1 "	1	1 Semy			252.745
8 Cups	1 Gill			4	3	29.	2 "	8	1 Unce		4	271.96
8 Gills	1 Quart		2	3	3	59.	4 "	64	1 Libra	2	4	425.68
8 Quarts	1 Octa	2	1	11	7	54.	8 "	512	1 Stone	18	7	342.94
8 Octas	1 Modius	17	5	15	7	18.	16 "	4096	1 Pondus	147	14	118.52
8 Modiuses	1 Pipe	141	7	15	2	24.	32 "	32768	1 Ton	1183	2	73.16
8 Pipes	1 Butt	1135	7	10	3	12.	64 "	262144	1 Load	9465	1	147.78
8 Butts	1 Hold	9087	5	3	1	36.	128 "	2097152	1 Keel	75720	10	307.24

would take the place of the following 19 weights, which are now used to accomplish nearly an equivalent purpose, viz: ½ grain, 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 60, 120, and 240 grains troy together with avoirdupois weights of 1, 2, 4, 8 and 16 ounces. These 19 weights make a total of 14104 grains, and would consequently be sufficient to weigh any number of half grains from 1 to 28208.

Upon examination of the above table, it will be seen that the *mite* is very nearly equal to half a grain, the difference being $\frac{64}{10.000}$, or about $\frac{1}{156}$th of a grain; *two mites* being about $\frac{1}{78}$th less than one grain; one *carat* is very nearly equal to 4 grains, being about $\frac{1}{20}$ grain less. One *scrap* is about 1½ grains more than the half drachm. One *semy* is 34 grains more than half an ounce avoirdupois, or 12¾ grains more than half an ounce troy; while four *unces* are equal to 18½ ounces avoirdupois nearly.

Of the fluid measures the *ligule* is equal to half a fluid-drachm and 3.2 minims; *two ligules* being 6.4 minims more than a fluid-drachm, or the medicinal teaspoonful; the *cup* is equal to 4 fluid-ounces and 3½ fluid-drachms; 4 *gills* are equal to 1 pint and 1¾ fluid-ounces, and the new *quart* is equal to two pints and 3½ fluid-ounces.

The smaller of these weights and measures assimilate so nearly with our present divisions, that for most practical purposes in medicine, pharmacy, etc., the difference would be inappreciable. It is true that all the valuable knowledge that clusters about the grain weight, in statistics of all kind, would have to be recalculated in the new weights, but as has before been stated this is a necessary consequence of *any* alteration in our unit.

If instead of retaining our linear unit, the inch, we had selected the grain weight, all of our weights would have been in even grains, while our measures would have been fractional quantities; in this case, instead of taking the inch, we would take the length of one side of a cube of water weighing at its greatest density 256 grains; such a cube would vary very slightly from a cubic inch; its side would measure 1.004334 inches; sixteen times this length would give us a "*Module*" equal to 16.069344 inches, and our "*Pondus*" would weigh 149 lbs., 12 oz. and 326 grains; our "*scrap*" would be exactly 32 grains, our "*carat*" exactly 4 grains, and our "*mite*" exactly half a grain.

It is believed that the scheme here proposed, independently of its merits, would less disturb our present system of weights and measures than any that has yet been proposed, and would be, therefore, more easily introduced and willingly accepted.

And has not the time arrived in the general progress of commercial and international intercourse, and the rapid advance of our country in science, wealth and power, when her voice should be heard in an important matter like this! Should not our Congress invite all nations to appoint suitable persons to be their representatives in a universal convention to be assembled for the purpose of devising and establishing a system of uniform weights and measures, practically applicable to the need and use of all peoples of the earth?

Such action could not fail to meet with a response due to the importance of the subject; and if the great object be attained, to lead to results productive of vast and lasting benefit to the human race.

These suggestions are offered for the purpose of promoting discussion, investigation, and consideration of the subject in all its bearings, in the hope that when the time arrives in which a change must be made, and such a time will inevitably come, that a system may be adopted which has been, or can be demonstrated to possess the greatest advantages, and is admitted to be, of all schemes proposed, the truest, the wisest, the best.

NOTE A.

"The triumph of the art of calculation, and that to which mainly the modern system of numerical computation owes its perfection, consists in the 'device of place,' by which all necessity for distinguishing the nature of the units signified by any symbol is superseded. Like many other inventions of the highest utility this, when known, appears to arise so naturally and necessarily out of the exigencies of the case, that it must excite unqualified astonishment how it could have remained so long undiscovered. * * * That the honor of the invention of a system which produced such important effects as well on the investigations of science as in the common concerns of commerce, should be claimed by many contending nations, is what would naturally be expected. * * * All Arabian authors on arithmetic appear to agree that the first writer of that country upon this system of arithmetic was Mohammed ben Muza, the Khuwarezmite, who flourished about the year 900. This writer is celebrated for having introduced among his countrymen many important parts of the science of the Hindoos, to the cultivation of which he was devotedly attached; and among other branches of knowledge thence derived, there is satisfactory evidence that this species of arithmetic was one. From the time of Mohammed ben Muza the figures and modes of calculation introduced by him were generally adopted by scientific writers of Arabia, although a much longer period elapsed before they got into common popular use, even in that country. They were always distinguished by the name *Hindasi*, meaning the Indian mode of computation. * * * At the beginning of the eleventh century the use of the Arabic notation had become universal in all the scientific works of Arabian writers, and more especially in their astronomical tables. The knowledge of it was of course communicated to all those people with whom the Moors held that intercourse which would lead to a community of scientific research. In the beginning of the eleventh century the Moors were in possession of the southern part of Spain, where the sciences were then actively cultivated. In this way the use of the new arithmetic was received into Europe first in scientific treatises. A translation of Ptolemy was published in Spain in 1136, in which this notation was used; and after this period it continued in general use for the purposes of science. Notwithstanding the knowledge and practice of this superior notation by scientific men, the Roman numerals continued to be used for purposes of business and commerce for nearly three centuries, and it was only by slow and gradual steps that the improved notation prevailed over its clumsy and incommodious predecessor. The first attempt to introduce it for the purposes of commerce was made by a Tuscan merchant, Leonardo Pisano, in 1202. Having

traveled in Barbary, he there learned the method of Hindoo arithmetic, and, struck with its superiority over that to which he had been accustomed, he determined that his countrymen should no longer be deprived of the benefits of it. He accordingly published his treatise in the Latin language; in which he professes to deliver a complete doctrine of the numbers of the Indians. * * * A considerable period, however, was necessary to introduce this system into the common business of life. The extensive commerce maintained by the Italian States directed their attention to the subject at an earlier period than other nations; and although, for scientific purposes, the date of the introduction of the Arabic numeration into Spain is earlier than that of its appearance in Italy, yet its use for the common business of life prevailed at a much earlier period among the Italian States than in any other nation of Europe" (*Lardner's Treatise on Arithmetic*, Book i, ch. ii).

The Hindoo numerals are found in various manuscripts of Italy bearing the dates 1212, 1220, 1228. But none are found in England till nearly two centuries later. Chaucer, the poet, who died in 1400, alludes to them in one of his poems as "*the figures newe*."

According to Sir John Bowring ("Decimal System," pages 23–30), the first calendar in the English language in which the Hindoo numerals are employed, bears the date of "1431," and the earliest date known on a tombstone in these figures is "1454," the tombstone being that of "Elen Cook," in the church at Ware. The first English book which bears its date in these figures is the "*Rhetorica Nova*, Gulielmi de Saona, 1478." And in seals only one example has been found anterior to the sixteenth century, which bears the date 1484. "The Roman figures lingered longer in England," adds Bowring, "than in any other part of the European world, having found an asylum in the dark and dull regions of the Exchequer" (page 26). "It is indeed scarcely credible that the perplexing and entangled manner of keeping accounts by the Roman numerals, in the same barbarous style which was practised before the Norman Conquest, was maintained at the Exchequer almost down to the present day. * * * In addition to this strange and absurd system of Exchequer book-keeping, tallies continued to be used down to the year 1782. It was only in the year 1831 that the Committee on Public Accounts, of which I was the secretary, recommended the utter and complete abolition of the ancient system and the adoption of the Indian numerals. It was in consequence of this change that in the year 1835 the *tallies* were ordered to be burnt; a conflagration which led to the destruction of both Houses of Parliament—the Exchequer in which the tallies were kept having formed a part of the ancient edifice of St. Stephen's" (*Sir John Bowring's Decimal System*, pages 124–125).

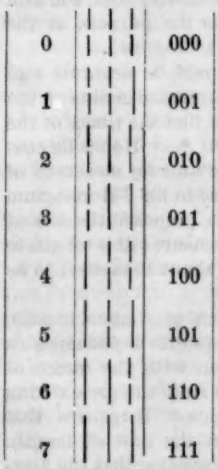
Delambre regards it as a fact humiliating to the pride of human genius that the discovery of the true notation of numbers by nine digits and zero should have escaped the sagacity of the illustrious geometers and mathematicians of ancient Greece. "The Hindoos," says Peacock, "consider this method of numeration as of divine origin. The invention of nine figures with the device of place being ascribed to the beneficent Creator of the universe. Of its great antiquity amongst them there can be no doubt, it having been used at a period certainly anterior to all existing records". (*Encyclopedia Metropolitana*). It can be traced back with certainty at least four centuries before its appearance among the Arabs, and as Lardner well re-

marks, since "none of these Hindoo authors claim either for themselves or their predecessors the invention of this method of enumeration, but always mention it as being received from the Deity, we may infer that it was practised in that country beyond the limits even of tradition." The Indian origin of our numerals being thus so well established, there is a manifest impropriety in continuing to designate them as the "Arabic figures," as is constantly done in our school arithmetics. Let us give honor where honor is due.

Note B.

It is remarkable that this binary system, according to the opinion of many, was used in China, four thousand years ago, by Fohi, the founder of the empire. A tablet of great but unknown antiquity, called the Cova of Fohi, marked with a series of variously broken lines, and held in superstitious reverence by the Chinese, as containing the mystery of a divine wisdom, has been found to be completely deciphered by the notation of binary arithmetic. When Leibnitz had extensively circulated his scheme or invention through the various scientific journals, and by means of his own correspondence—it appears to have found its way even to China, and to have attracted the attention of a Jesuit missionary at Pekin, named Bouvet. This ecclesiastic, engaged at the time in the study of the Chinese antiquities, discovered and immediately communicated to Leibnitz, with much exultation and enthusiasm, the surprising fact that his system furnished a perfect key to the mysterious lines upon the ancient Cova—hitherto inscrutable, or interpreted only by the speculations of the most extravagant mysticism. The lines of Fohi are arranged in an octagonal form, so as to make the ends approach; each set of the eight series being disposed on a side of the octagon.

These lines transferred from the Cova tablet, and placed in a straight line, are here represented. The row of figures in front expresses the value of each compound symbol, the other figures, which represent the binary notation, manifestly exhibiting a perfect correspondence with the symbols throughout.



"These figures of eight cova," says Mr. Peacock, (in the *Encyclopedia Metropolitana*), "are held in great veneration, being suspended in all their temples, and though not understood, are supposed to conceal great mysteries, and the true principles of all philosophy, both human and divine."

This inscription is exceedingly interesting as exhibiting a true example of that philosophic notation, the device of the cipher—and the determination of value by place. The absence of any other traces of such a notation in China, and its well-known antiquity in India, where it had been so fully elaborated, would lead to the suspicion that it was to this latter country that Fohi was indebted for this curious record of ingenious thought. It appears that Bouvet was fortunate enough to find, subsequently, a Great Cova, in which these markings were carried to a period eight times the extent of the Small Cova. In the *Edinburgh Encyclopedia*

(Article "Arithmetic"), it is stated in reference to this subject, that Father Bouvet, who first suggested this explanation and communicated it to Leibnitz, afterward procured, during his residence in China, the *Great Figure of Fohi*, which extends as far as 64. The exact coincidences which he still found to prevail between the combinations of these lines and the figures of the binary notation, left no doubt with regard to the justness of his conjecture; and we cannot help remarking that the restitution of the true sense of those characters, after so long an interval of time, is a very singular fact in the history of science.

Note C.

It is interesting to trace the history of the gradual development, in modern times, of the grand but difficult project of obtaining from nature a constant and universal standard of length. It is obvious that no such objects of ultimate reference as the human foot, or arm, or cubit, or as "thirty-six barley corns round and dry," can be regarded as natural standards, since they are wholly useless for the purpose of any precise determination. And all measures derived from them are purely arbitrary, as their authority is obtained from positive enactment, merely, and not from any agreement with their nominal originals. Hence it is not at all surprising that "cubits" and "feet" come to signify anything the civil power may enact; the former of these denominations ranging through every gradation of value, from the *covid* of 14¼ inches to the royal Egyptian *cubit* of 25¼ inches, and the latter from the Pythic foot of 9¾ inches, to the Geneva foot of 19 inches. Nor would it ever be possible from such sources, to reproduce a lost standard, with even the rudest approach to exactness. As Mr. Adams has well remarked, "For all the uses of weights and measures in their ordinary application to agriculture, traffic, and the mechanic arts, it is perfectly immaterial what the natural standard to which they are referable may be. The foot of Hercules, the arm of Henry the First, or the barley-corn is as sufficient for the purpose as the pendulum, or the quadrant of the meridian" (*Report to Congress*).

"The first attempt at fixing such a standard as should be accurate and universal, both as to place and time, is due to the inventive genius of the celebrated Huyghens. That philosopher demonstrated that the times of the vibrations of pendulums depend on their length only. * * * Hence he conceived that the pendulum might afford a standard or unit for measures of length" (*Edinburgh Review*, Vol. ix, page 373). It was in his "Horologium Oscillatorium" (published about 1670), that Huyghens proposed the use of the seconds' pendulum as a universal and perpetual measure; this length to be divided into three equal parts; and this third part (about 13 inches) to be called the *horary foot.*

The celebrated Picard, who first measured from Paris to Amiens in 1669, an arc of the meridian in France, making the degree equal to 68.945 miles (a measurement memorable as having furnished Newton with the means of verifying his grand theory, incapable of determination from the pre-existing data), also proposed in 1671, in agreement with the idea of Huyghens, that the pendulum beating seconds should be adopted as the unit of length. Picard has the merit of having first thrown out the suggestion that the diurnal rotation of the earth ought to affect the oscillation of the pendulum, and

that it ought to vibrate more rapidly toward the poles than toward the equator. He accordingly tried the pendulum at Uranibourg, at Paris and at Cette, but was not fortunate enough to discover any sensible difference. Roemer also found the length the same at London.

Richer, however, in the same year, 1671, or early in 1672, while engaged in the duties of his commission at Cayenne, on observing the length of the seconds' pendulum at this place (lat. 4° 56′ north of the equator), found it sensibly shorter than at Paris (48° 50′ north), the difference being about a line and a quarter. Richer's discovery that the pendulum varied in length with the latitude, deprived it of that uniform character considered so necessary in a linear *standard*.

The Abbe Gabriel Mouton, a distinguished mathematician who flourished at the same time, appears to be the first who suggested a measure derived from the earth. He proposed, almost simultaneously with the publication of Huyghens, a *decimal system of measures* based on the value of a minute of arc, as derived from Riccioli's length of a degree. This minute of the degree he called a *miliare*, the thousandth part of which he called a *virga*, equal to 5 feet 4⅛ inches. We have here the germ of the present French metrology.

Cassini, who in 1718 repeated the measurements of a meridian made by Picard (extending his arc, however, further south, namely, from Paris to Dunkirk, and making the degree 69.119 miles), proposed the earth's radius as the unit of length. He afterward in his book, "*De la Grandeur de la Terre*," proposed as a unit the six-thousandth part of a minute of a degree of a great circle of the earth, a measure very nearly equal to the foot.

In 1748 M. de la Condamine (who had recently returned from measuring a degree at the equator in Peru), in a memoir read before the Academy of Sciences, resumed the idea of the pendulum as the unit of length, proposing that it should be taken as beating seconds at the equator, as the most notable line of latitude, and as one likely to avoid all the prejudices which might arise from national jealousy were the latitude of any particular place selected. We see from this the anxiety felt to secure a standard which might be common and uniform among nations.

On the 15th of January, 1790, in accordance with President Washington's recommendation, the House of Representatives

"Ordered, That it be referred to the Secretary of State to prepare and report to this House, in like manner, a proper plan or plans for establishing uniformity in the currency, weights and measures of the United States."

n the 15th of July of that year the House of Representatives received from the Secretary of State (Mr. Jefferson) his report of the proper plan for establishing the desired uniformity, as requested by the House.

In this elaborate report the Secretary proposed "that the standard of measure be a uniform, cylindrical rod of iron of such length as, in latitude 45°, in the level of the ocean, and in a cellar or other place, the temperature of which does not vary through the year, shall perform its vibrations in uniform and equal arcs in one second of mean time."

Starting from this standard, he proposes two distinct plans for the consideration of the House, that they might, at their will, adopt the one or the other exclusively, or the one for the present and the other for the future time, when the public mind may be supposed to have become familiarized to it.

The first plan was *to define and render uniform and stable the existing sys-*

tem; to make the foot to bear a definite ratio to the standard pendulum rod; to reduce the dry and liquid measures to corresponding capacities by establishing a single gallon of 270 cubic inches, and a bushel to be equal to eight (8) gallons, or 2,160 inches—that is, to one and one-fourth cubic feet; to make the ounce to be the weight of one-thousandth part of a cubic foot of water; to retain the more known terms of the two kinds of weights in use, reduced to one series; and to express the quantity of pure silver in the dollar in parts of the weight so defined.

The second plan was to reduce "every branch to the same decimal ratio already established in coins, and thus bring the calculation of the principal affairs of life within the arithmetic of every man who can multiply and divide plain numbers."

Except in the length of the fundamental unit, and in the nomenclature, this was essentially that of the metrical system of France.

These two plans were sharply opposed to each other, and it was to be expected that the desire for a decimal division, and symmetry of system on the one hand, and the reluctance to make a violent change on the other, should elicit no little discussion.

This report was communicated to the Senate in December of that year and referred to a committee. That committee reported on the 1st of March, 1791, that, "as a proposition has been made to the National Assembly of France for obtaining a standard of measure which shall be invariable, and communicable to all nations and at all times; as a similar proposition has been submitted to the British Parliament in their last session; as the avowed object of these is to introduce an uniformity in the measures and weights of the commercial nations; as a coincidence of regulation by the Government of the United States on so interesting a subject would be desirable, your committee are of opinion that it would not be eligible, at present, to introduce any alteration in the measures and weights which are now used in the United States." This report was adopted.

In 1790, Talleyrand proposed to the constituent Assembly of France, that in view of the great diversity and confusion in the weights and measures of the country, a commission should be appointed for the purpose of consulting with a similar commission from the English Government, upon the subject of establishing a uniform international system of metrology, founded upon a single and universal standard. The proposal alluded to the only two natural standards which presented themselves, viz., the measure of the earth and the pendulum, and expressed a decided preference for the latter. The result of this movement was the appointment of Borda, Lagrange, Laplace, Monge, and Condorcet, as commissioners to examine into and report upon the subject. After a careful consideration of the three plans submitted, namely, the pendulum, a quarter of the equator, and a quarter of the terrestrial meridian, they very judiciously agreed in decidedly recommending the latter; regarding the pendulum as an unsuitable standard, whether taken at forty-five degrees of latitude or at the equator.

The attempt to enlist the co-operation of England proved abortive. "The operation of changes of opinion there," says Mr. Adams, "is slow—the aversion to all innovations deep. More than two hundred years had elapsed from the Gregorian reformation of the calendar, before it was adopted in England. * * * After a succession of more than sixty years of inquiries and

experiments, the British parliament have not yet acted in the form of law" (*Report to Congress*).

Just five hundred years after the statute of 17th Edward II (A.D. 1324), enacted that "three barley-corns round and dry, make an inch—twelve inches make a foot," etc., the first change was made in the legal definition of the foot. By the act of 5th George IV, c. 74 (1824), it is declared "the standard yard is the distance between the centres of the two points on the gold studs in the straight brass rod now in the custody of the Clerk of the House of Commons, whereon is engraved 'Standard yard, 1760,' the brass being at the temperature of 62 degrees of Fahrenheit's thermometer." "The Yard, if lost, defaced, or otherwise injured, may be restored by comparing it with the pendulum vibrating seconds of mean time in the latitude of London, in a vacuum, on the level of the sea, the yard being in the proportion of 36 inches to 39.1393 inches of the pendulum." This was the first attempt to refer the English foot to a natural standard.

Ten years afterward, or in 1834, the contingency provided for by this statute actually occurred by the burning of the Houses of Parliament; in which conflagration the celebrated brass standard of Bird was destroyed. Although the only actual legal standard was thus lost, no attempt was made to restore it by the pendulum, as provided by law; but the mean of several different standards, including one belonging to the Royal Astronomical Society (fortunately the Astronomical Society had procured a most carefully prepared copy of the imperial standard yard, and the Mint was in possession of an exact copy of the pound), was selected as giving the nearest approximation to the legal standard yard.

A commission was appointed by the British Government, in 1838, "to consider the steps to be taken for the restoration of the Standards of Weight and Measure." The commissioners in their report, made in 1841, say: "We are of opinion that the definition contained in the Act 5, Geo. IV, c. 74, ss. 1 and 4, by which the standard yard and pound are declared to be respectively, a certain brass rod and a certain brass weight therein specified, is the best which it is possible to adopt. Since the passing of the said act, it has been ascertained that several elements of reduction of the pendulum experiments therein referred to are doubtful or erroneous; thus the reduction for the weight of air was erroneous; the specific gravity of the pendulum was erroneously stated, the faults of the agate plates introduced some degree of doubt, and sensible errors were introduced in the operation of comparing the length of the pendulum with Shuckburgh's scale, used as the representative of the legal standard. It is evident, therefore, that the course prescribed by the act would not necessarily reproduce the length of the original yard. Several measures however exist, which were most accurately compared with the former standard yard. And we are fully persuaded that, with reasonable precautions, it will always be possible to provide for the accurate restoration by means of material copies which have been carefully compared with them, more surely than by reference to any experiments referring to natural constants." And the report concludes by recommending "that the standard of length be defined by the whole length of a certain piece of metal or other durable substance, supported in a certain manner, at a certain temperature; or by the distance between two points or lines engraved upon the surface of a certain piece of metal or other durable substance, supported in a certain

manner and at a certain temperature; but that the standard be in no way defined by reference to any natural basis, such as the length of the pendulum vibrating seconds in a specified place. * * * That the standard of weight be defined by a certain piece of metal or other durable substance," etc.

It thus appears as the result of this last commission in England, that the people of that country are disposed to abandon all attempts at obtaining a natural standard, and to recur to the authority of an arbitrary rod or piece of metal, whose length has been derived from prescriptive custom. It should be considered, however, that after a natural standard has been obtained, we still have all the means of its material perpetuation, suggested in the commissioners' report. And no foreign community is ever likely to accept as an authoritative unit of measure, a certain brass rod manufactured in England, and incapable of any more precise definition.

Mr. Baily was selected to prepare the new standard, having five copies of the preceding on which to base his comparison; on his death, in 1844, Mr. Sheepshanks continued the necessary observations. Of several standard copies finally prepared by him, each being a square inch bar, of a bronze consisting of copper with a small percentage of tin and zinc, 38 inches in length, with half inch wells sunk to the middle of the bar, one inch from each end, in which the lines defining the yard are drawn on gold plugs—six were finally selected and reported by the commissioners in March, 1854. Of these, the one marked "Bronze 19" was selected as the parliamentary standard yard, the remaining five being deposited, along with copies of the standard of weight, with as many public institutions and scientific bodies. These standards were legalized in July, 1855; and in case of loss of the parliamentary copy, it was provided that the standard should be restored by comparison of the other selected copies, or such as might be available.

Bronze bar No. 11 which has the standard length at a temperature of 61.79° has been presented to the United States, and is the actual standard of comparison.

In addition to the difficulties of obtaining from the pendulum the reconstruction of a lost standard, as above indicated, it is not unimportant to note that there is an original uncertainty in the determination of its length, of nearly the thousandth part of an inch. "We cannot venture to say that the clock's rate in a given day, can be determined certainly to within one-tenth part of a second, although the comparisons have been made at an interval of 24 hours. Seeing then that the *free* pendulum is compared with the clock only over a small fraction of the day, it is a great deal to expect that *its* daily rate can be ascertained to within one second of time. A change of one second per day in the rate of a clock, corresponds to a change of $\frac{1}{43200}$, in the length of the pendulum, which is about $\frac{1}{1100}$ of an inch, or $\frac{1}{43}$ of a millimetre; and therefore we may regard this distance as indicating the probable limit of exactitude" (*Encyclopedia Britannica*, 8th edition, Vol. xvii, page 384, article "Pendulum," by Edward Sang).

Note D.

The only account we have been able to obtain of the important movement of Charles XII toward superseding the decimal by the octonary system, throughout Sweden, is that contained in a volume entitled "A Compendium

of the Theological and Spiritual Writings of Emanuel Swedenborg" (royal octavo), published at Boston by Crosby & Nichols, 1854. In the life of Swedenborg, prefixed to the "Compendium," it is said: "In 1719 he published four works; first, '*A Proposal for fixing the value of Coins and determining the Measures of Sweden, so as to suppress fractions, and facilitate Calculations.*' After which he was commanded by his Sovereign to draw up an Octonary Computus (a mode of computing by eighths), which he completed in a few days, with its application to the received divisions of Coins, Weights, and Measures; a disquisition on Cubes and Squares, and a new and easy way of extracting Roots; all illustrated by appropriate examples" (Life, p. 9). As Swedenborg devised for his "Octonary Computus," both a set of characters and of new names, we were exceedingly anxious to have enriched this Paper with their representation. We have failed, however, to find any clue to these early publications in any of the public libraries or private collections to which we have had access. The only additional reference to the subject in the volume above referred to, is contained in a letter from Swedenborg to M. Nordberg, written after the death of Charles XII, which appears to detail the monarch's first conception of the project of a reformation in the popular system of numeration. An extract giving all that relates to the subject of octonary computation, is here copied:

Letter of M. Swedenborg, Assessor of the Board of Mines, to M. Nordberg, Author of the History of Charles XII.

"SIR:—As you are now actually engaged upon the Life of Charles XII, I avail myself of the opportunity to give you some information concerning that monarch, which is perhaps new to you, and worthy of being transmitted to posterity. * * * Conversing one day with the King upon arithmetic, and the mode of counting, we observed that almost all nations, upon reaching ten, began again; that those figures which occupy the first place, never change their value, while those in the second place were multiplied ten-fold, and so on with the others; to which we added that men had apparently begun by counting their fingers, and that this method was still practised by the people; that arithmetic having been formed into a science, figures had been invented which were of the utmost service; and, nevertheless, that the ancient mode of counting had been always retained, in beginning again after arriving at ten, and which is observed by putting each figure in its proper place.

The King was of opinion that had such not been the origin of our mode of counting, a much better and more geometrical method might have been invented, and one which would have been of great utility in calculations, by making choice of some other periodical number than 10. That the number 10 had this great and necessary inconvenience, that when divided by 2, it could not be reduced to the number 1, without entering into fractions. Besides, as it comprehends neither the square, nor the cube, nor the fourth power of any number, many difficulties arise in numerical calculations. Whereas, had the periodical number been 8, or 16, a great facility would have resulted, the first being a cube number of which the root is 2, and the second a square number of which the root is 4; and that these numbers being divided by 2, their primitive, the number 1 would be obtained, which would be highly

useful with regard to money and measures, by avoiding a quantity of fractions. The King, after speaking at great length on this subject, expressed a desire that we should make a trial with some other number than 10. Having represented to him that this could not be done unless we invented new figures, to which also names altogether different from the ancient ones must be given, as otherwise great confusion would arise, he desired us to prepare an example in point. We chose the number 8, of which the cube root is 2, and which being divided by 2, is reduced to the primitive number 1. We also invented new figures, to which we gave new names, and proceeded according to the ordinary method; after which we applied them to the cubic calculations, as well as to money, and to measures. The essay having been presented to the King, he was pleased with it" (*Appendix to Life, etc.*, pp. 123, 124).

On the so-called Alaguilac Language of Guatemala.

By D. G. Brinton, M.D.

(*Read before the American Philosophical Society, Nov.* 4, 1887.)

In his valuable treatise on the ethnography of the Republic Guatemala, Dr. Otto Stoll classes the Alaguilac language, once spoken by a tribe resident on the Motagua river in that country, among the languages of unknown affinities, *Sprachen unbekannter Stellung;* and he also adds, that at the time of his visit to the vicinity—now about five years ago—the tongue was entirely extinct, being supplanted by the Spanish.*

It were greatly to be regretted that any language or dialect should perish completely, leaving no record behind it by which we can assign its place in the linguistic scheme. I am happy to say, this is not the case with the Alaguilac. I have in my hands materials from several sources from which to identify this now extinct tongue, and also to cast some interesting glimpses on the ancient civilization of the tribe which once spoke it. These sources are:—

I. Four leaves in folio, originals, from the archives of the Parish of San Cristobal Acasaguastlan, dating from 1610 to 1637, in bad condition, but mostly legible.

II. A collection of words and phrases obtained in 1878 by Francisco Bromowicz from an Indian woman at the village of

* Stoll, *Zur Ethnographie der Republik Guatemala*, s. 172. Also, *Guatemala, Reisen und Schilderungen*, s. 304.

San Augustin Acasaguastlan, named Dolores Corral, then supposed to be one hundred years old or over, and the last of her tribe who could recall the native tongue. Bromowicz appears to have visited the village on the instigation of Don Juan Gavarrete, the well-known Guatemalan antiquary, or of Dr. C. H. Berendt, or of both.

III. Several *informes* of Don Eligio Pais, municipal judge of Chiquimula, and of the cura or parish priest of San Cristobal Acasaguastlan, Don José Inocente Cordon, dated in 1878.

With these means I am enabled to throw sufficient light on the affinities of the Alaguilac language, and add something to our knowledge of the archæology of the locality.

First, a few words on its geographical location.

The parish of San Cristobal Acasaguastlan is situate on the Motagua river in Guatemala, department of Chiquimula, forty-five miles northwest of the city of Guatemala. Its dependencies are the hamlets of Chimalapan, Usumatlan and Tecolutan. About eight miles to the east of it, is the parish of San Augustin Acasaguastlan, whose inhabitants formerly spoke the same tongue.

In the letter descriptive of this region sent to the King of Spain, in 1576, by the Licentiate Diego Garcio de Palacio, he says briefly, "in the valley of Acacevastlan is spoken the Tlacacebastleca."* In the list of languages current in Guatemala as given by the historian Juarros, at the beginning of this century, no such tongue is mentioned, but in place of it, apparently, he names the *Alaguilac*.† The ordinary native tongue of that part of the valley is the Chorti, a dialect of the Maya of clear affinities, and all the surrounding tribes belong to the Maya stock.

At present, as we have seen, travelers agree in the statement that all the Indians of Acasaguastlan speak Spanish only, and the Alaguilac is reckoned therefore among the extinct tongues of America.

The place-names mentioned in these accounts are clearly of Nahuatl origin. Acasaguastlan‡ is a slight modification of *acaga-*

* *Carta de Garcia Diego de Palacio*, p. 20. Ed. Squier.

† *Historia de Guatemala*, Tom. II, p. 35.

‡ The term given by Palacio—Tlacacebastleca—is a derivative under the ordinary rules of Nahuatl grammar from Acaçacatlan, the termination *eca* being the plural of the *suffix gentilis*, *ecatl*, and the prefix *tla*, meaning here the thing possessed by or peculiar to these people.

catlan the place of rushes or reeds; Chimalapan is compounded of *chimalli*, a shield, with the post-position *pan*, in or at; Usumatlan means the place of monkeys, from *ozumatl*, monkey, and *tlan*, locative ending; and Tecolotan, the place of owls, from *tecolotl*, owl, and *tlan*. The word Alaguilac is stated in the MSS. before me to be the Mexican name of a species of edible fruit; though were it not for this authority, one might suppose it to be from the *nomen gentile*, *atlacuilecatl*, which means "the people who live at the place of drawing water" (*atl*, water, *cui*, to take, *ecatl*, terminatio gentilis).

Evidently, therefore, we find ourselves in a Nahuatl colony, one of those which were scattered through Central America, like the Pipiles of Escuintla, and the Nicaraos in Nicaragua. It has been shown recently that this active race extended its settlements almost to the isthmus of Panama, and established a colony on the borders of the Chiriqui Lagoon.*

Everywhere they carried with them reminiscences of that advanced culture which they had developed in the Valley of Mexico. This is manifest to-day by the superior make of pottery and the fragments of stone and brick edifices which mark the site of their ancient abodes.

Acasaguastlan is no exception to this rule. In the *informe* of the worthy cura above mentioned, he writes as follows:—

"At the confluence of the Rio Grande de Acasaguastlan [*i. e.*, the Motagua river] with that of Teculutan, which is to the east of this parish, there are some prominent and remarkable relics of a dense native population, which prove this to have been the capital of a province. There are neat, level pa ements which lead from the buildings to the river. The buildings themselves indicate that they were towers or pyramids. The base is circular and they must have had an altitude of fifty Spanish yards (varas). At present they are covered with lofty trees, and the ruin on the promontory, now the highest, is sixteen or twenty yards in height. In the midst of these edifices, at the place named, there is a large open space, circular in form, like a plaza. A continuous row of mounds extends from these edifices and pyramids, on both sides of the main river, to the village of Acasaguastlan.

* A. Pinart, in the *Revue d'Ethnographie*, Tome vi, p. 121, identifies the Seguas Indians of the Chiriqui Lagoon with the Nahuas.

One of these has been demolished, and proved to be of stone, yielding as much as two hundred perches, without counting the cement. Each of them contains an arch either complete or in ruins. In the one mentioned, three small arches were found, constructed with some symmetry, but it was not ascertained whether the material was joined by lime, as at present it looks more like clay. Portions of the wall were smoothly plastered and some nearly erased paintings were visible. In the structure were found earthen pots, some roughly made, others of excellent workmanship, and with them incense burners, such as the Indians use at the present day in their Brotherhoods (cofradias). There were also found pieces of brick, much like foreign brick, meal-stones in the shape of large shells, arrow points of glass [*i. e.*, volcanic glass, obsidian], and human bones. No one has taken special interest in investigating these remains, and I have known persons who seemed quite intelligent pass by them without awarding them the least attention, and as if they did not see them. Finally, I add that I am assured that no precious metal has been discovered in them, although they may have had antimony, which the Indians used to polish their earthenware as it is quite lustrous."

Such is the interesting description furnished by the parish priest, and it reveals plainly that the ancient race of Acasaguastlan belonged among the more highly cultivated nations of the continent.

I have not found in the historians of Guatemala the records of the first exploration of this portion of the valley of the Motagua, nor in later travelers the account of any visit to these ruins. It would be of especial interest to determine whether they approach the distinctively Mexican or the Maya style of architecture. The presence of the arch points to the latter, but this architectural element was not altogether foreign to the former.

Fifty miles as the bird flies, lower down the Motagua river, are located the remarkable ruins of Quirigua, with their elaborately carven monoliths, twenty feet or more in height. According to the most recent observers,* these relics present evidences of an antiquity greatly exceeding that of Copan or Palenque, both which venerable sites had long been deserted at the period

* See *Copan und Quirigua*, by Heinrich Meye and Dr. Julius Schmidt, Berlin, 1883.

of the Conquest. The valley of the river Motagua, therefore, was probably one of the centres of Central American civilization, and a study of its archæology might prove peculiarly productive.

The reduction and conversion of the tribe dwelling at Acasaguastlan probably took place before the middle of the sixteenth century. The intelligent members of the community were taught to read and write their native tongue, and the records in my hands are by native scribes, who kept these notes or accounts in order to submit them from time to time to their civil or ecclesiastical superiors.

These records are in a dialect of Nahuatl closely akin to that of the Pipiles of Escuintla and the neighborhood. Both dialects are but slight modifications of the tongue as spoken in its purity in the Valley of Mexico. Perhaps much of the apparent difference is due to an uncertain orthography and the inexpertness of the writers.

The subjoined extracts from the archives under the dates 1610, 1634, 1636 and 1637, will show conclusively that the Nahuatl was the current tongue of the parish at that time. The entries relate to fines which were imposed on the natives for various misdemeanors, and of which the civil officers were obliged to pay a portion from time to time to their superiors. The receipts of these superiors are entered in Spanish in the archives and present the honored autographs of Juan de Montoya and G. de Mendieta.

Although various Spanish words occur, and the imperfect handwriting as well as the poor condition of the MSS. render these specimens less satisfactory than could be wished, it will nevertheless be apparent at a glance that the dialect is a tolerably pure Nahuatl, such as was common in Mexico a century after the Conquest.

Extracts from the Parochial Archives of San Augustin Acasaguastlan.

Y nipan 20 de Octubre 1610 años niman in teguantin S^{or} Don Fra^{co} Castro Bernabe de Chaves Christobal Hernandez attos Ju^{o} Perez niço Melcjior Perez tiri Gaspar Lopez Chuvuru Augustin Hernandez rexidores nican vticchiuaque condenat yei tupilhuan

ypanpa onomictique (two words illegible) ica ce ciuat itoca Magdalena ica iztaca tihi vquichiuaque yuan nican Catalina Curmi quezqui ipanpa vticpenaltique vquitali ome tostones Gaspar ci timal vquitali chiquacen tomin Catalina Curmi yuan Di° Salualtierra vquitali chiquacen tomin quezquiz ypanpa vneci nican macuili tostones.

* * * * * * *

Y nipan ome tonalli mesti de Mayo 1634 años ticpenaltique yei ciuatlque ipanpan omoqualantique ypan ytequiuh yquiti ce yc xi ticmati ypalta ermita sancta vneci nican m^{a} Ju^{a}na ce ynamic Fr^{co} cucu, ce ynamic P° mendes ce ynamic X°bal Her^{dz} yuqui ticpenaltique vneci nican matlacti tomin Andres Mendes Alcalde Gaspar Lopez Chucuru Alcalde Dg° her^{dez} D° Felipe Regidores noyxpan neuatl Baltasar de Gabes escribano cabildo.

* * * * * * *

1636 años.

Y nipan 24 de Abril 1636 años ypan vticpenaltique ome tupiluan omo tatani Justia ypanpa omohaçi ychau nican ciuatl vquitatani Justia X°ual permesso yuqui vneci yca auilnemiliz yeuatl ipanpa vticpenaltique X°ual Ruy mucuc yuan bernaldina yuqui ypanpa vneci nican chiquacen tostones teuantin alcaldes Fr^{co} caynac Diego Felipe yuan Regidores Anton mucho x°ual br^{me}bico Miguel Estorca Regidores.

* * * * * * *

Y nipan 23 tonali mesti de Junio 1637 años ypan vticpenaltique ome tupiluan omotatani Justi^{a} nican X°ual axpal ypanpa can qui talili y ciuauh yuqui vtictatanique ytic nican tu cabildo auin quitoua X°bal ypan vniquita vquia ce tacatl nochan ayac vniquixmati quitoua vqui melaua nican y ciuauh melauac yeuat X°bal her^{dez} ypanpa yeuat niquixmati opa espa ni mauilli yuan quitoua to yxpan teuantin altos Regidores yuqui ypanpa ticpenaltique vneci nican naui tostones can ixquich nican timoticmatique x°bal chururu Diego Felipe alcaldes gaspar macaua Ju° lopez a lo cauil Ju^{a} basqz Regidores no yxpan neuat Baltesar de Chabes es^{o} cabildo.

* * * * * * *

The words collected by Mr. Bromowicz number about 150, and according to the *informes* accompanying his report, were obtained

from the only person then living in the region who could recall the tongue of former generations. In the ten years which have elapsed since his visit, Dolores Corral has, doubtless, been gathered to her fathers, and the words of this vocabulary remain to us as the sole monument of the original speech of her tribe. Fortunately they are sufficient in number and clear enough in their affinities as to leave no doubt concerning their linguistic affinities. I present them in one column, arranged in alphabetical order, and by their side, their correspondents in the pure Nahuatl of the Valley of Mexico.

Comparative Vocabulary of the Alaguilac and Nahuatl.

Alaguilac of San Augustin Acasaguastlan.	*Nahuatl.*
Achko, above,	aco
achpoco, much,	ixachi
achtko, monkey,	quauhchimal
aktakaki, deaf,	nacatzatza
aschka, day,	tlacatli
at, water,	atl
atemet, a louse,	atemitl
atenko, spring, well,	(atenco, full of water)
atschi, man (vir.),	oquichtli
checheltek, red,	chichiltic
cholo, toad,	tama-çolin
chuvechka, far,	uehca
culut, a scorpion,	colotl
echegat, wind,	ehecatl
este, blood,	eztli
iagak, nose,	yacatl
ictle, good,	yectli
ikschi, foot,	ixitl
ima, hand,	maitl
imits, leg,	metztli
imperao, bad (Span. *imperito*),	
inachtaval, wing,	atlapalli
inagas, ear,	nacaztli
inenguajo, root,	nelhuayotl

ischko, eye,	ixtololotli
ischte, thread (Span. pita, the thread obtained from the Manguey),	ichtli
isoko, nest (of a bird),	çolli
istak, white,	iztac
istat, salt,	iztatl
istet, nail (of fingers or toes),	iztetl
isutschio, flower,	xochitl
itckses, egg,	tetototl (from *tetl*, stone, *tototl*, bird)
iti, mouth,	from *itia*, to drink. The Nahuatl for mouth is *camatl*
itscha, house,	chane
itschkat, cotton,	ichcatl
itsulteko-kali, roof,	ceuacaltia (*lit.*, to shade the house, *calli*)
kaits, shoes,	cactli
kiskuetspal, iguana,	
koehko, horn,	quaquauitl
koets, naguas (skirt),	cueitl
kot, tree,	quauitl
kotoschte, skin, leather,	cuetlaxtli
kott, firewood,	quauitl
kuat, snake,	coatl
kujol, jakal, coyote,	coyotl
kumit, pot, jar (olla),	cumitl
kusti, yellow,	coztic
meste, moon,	meztli
metat, metate,	metlatl
mischte, clouds,	mixitl
misto, cat,	miztli
munantse, mother,	mo-nantzin (thy mother)
muss, fire,	tlecocomoctli, flame
musta, to-morrow,	moztli
mutuchtsé, squirrel,	
mutsungal, hair,	mo-tzuntli, thy hair
nagat, flesh, meat,	nacatl
nekte, sweet,	necutic
neschta, ashes,	nextli
niamigi, thirsty,	ni-amiqui, I am thirsty

nimikukua, sick,	ni-mocuiqui, I am sick
notapetschko, bed,	no-tlapechtli, my bed
numitschi, fish,	no-michin, my fish
numpa, near,	ompa
nupiltsi, son,	no-piltzin, my son
nusiguapiltsi, daughter,	no-ciua-piltzin, my female child
pallo, dog (Spanish, *perro*),	
piltzinte, child,	piltzintli
pisti, hungry,	napizti
pittatsi, father,	tatzin
pokte, smoke,	pochotl
puran, plantain (Spanish, platano),	
sachti, wax,	
sagat, leaf of a tree,	zacatl, straw, grass
sajuli, a mosquito,	çayulin
schali, sand,	xalli
schigal, jicaro,	xicalli
schinamit, town,	chinamitl
schuguscho, sour,	chichic
schupanta, rain,	chachapani, to rain heavily
schuschuk, green,	xoxoctic
sesek, cool,	cecec
sigwat, woman,	cihuatl
sinti, maize,	cintli
soguitz, mud,	çoquitl
tali, earth, ground,	tlalli
taloa, yesterday,	yalhua
taschi, tortilla,	tlaxcalhuia
tecumat, calabash,	tecomatl
tekpe, flea,	tecpin
temesch, lime,	tenextli
teng-uej, very big,	cenca-uey
tepitschi, little,	tepiltan
tepitschil, grown-up child,	tepiltzin
teschuste, coal of fire,	tlexochtli, a spark
tet, stone,	tetl
tiltek, black,	tliltic
timaga, bat,	
temutalpa, a bee,	temoli

teng-totonki, very warm,	cenca-totonia
tepitschi, small,	
totonki, warm,	totonia
tschikaguaste, comb,	tziquauaztli
tschitschik, bitter,	chichic
tsigat, an ant,	tzilazcatl
tuschte, rabbit,	tochtli
tutuli, a chicken,	tototl
tutumuschti, ear of corn,	totomochtli (the dried husk or shuck of corn)
uchte, path, road,	otli
uej, big,	huey
uiste, thorn,	uiztli
umasat, deer,	mezatl
umit, bone,	omitl
unka, to-day,	axcan
tsotsogal, water pitcher,	tzotzocolli
tsunteko, head,	tzontli
tuak, night,	youalli
tucha, leaf of maize,	tocyzuatl
tutot, bird,	tototl
tugat, a spider,	tocatl
tun, sun,	tonatiuh

Phrases in Alaguilac.

Unka at, there is water.
Akten at, there is no water.
Schiwaka, come here.
Kapatia, Where goest thou?
Schuiesmaga muss, Give me some fire.
Qualiga taschi, Bring tortillas.
Qualiga se plato, Take the plate.
Queschki que tscho, How much is it?
Kalen-it agua, I want to eat.
Schitagua, Eat.

Numerals.

Alaguilac.	*Nahuatl.*
1. se	ce
2. umi	ome
3. jei	yei
4. nagui	nahui
5. makuil	macuilli
6. tschikuasi	chiquace
7. tschikume	chicome
8. tschikwei	chiculy
9. matakticumi	chicunaui
10. matakti	matlactli
20. sempual	cempvalli

The Nahuatl which I have placed in the comparative list represents that tongue in its oldest and purest form as given in the Dictionary of Alonso de Molina, printed in 1571. The comparison leaves no doubt whatever, that the Alaguilac was a quite pure form of the Nahuatl, and when we allow for the difference in the orthography of Bromowicz, who writes as a German, from that of Molina, the variation is surprisingly little. In the phrases the *schi* represents the usual Nahuatl imperative form *xi*, the *x* in that tongue having the sound of the German *sch* and the English *sh* in "she."

The only change which has taken place in the numerals is in the number nine, the substitution for *chicunaui*, "one hand and four fingers," of *matakticumi;* but I have no doubt this was a piece of forgetfulness on the part of the venerable Dolores, and that she gave the word for twelve, *matlactliome* (10 + 2), instead of that for nine.

Two questions will arise in the mind of the critical reader: 1. Did any other language exist at Acasaguastlan to which the name Alaguilac could have been applied? If not, and allowing it to have been merely a slightly altered form of the Nahuatl, was it introduced into that locality before or after the Conquest?

To the first of these questions, we may safely reply with a clear negative. There is not a native proper name in the vicinity but belongs either to Nahuatl or Chorti. There is not the slightest

evidence in the Nahuatl vocabulary of the influence of any *tertium quid*. We may positively exclude the supposition of a third, wholly lost and unknown tongue, and unhesitatingly identify the "Alaguilac" of Juarros, with the "Tlacabastleca" of Palacio, and both with the ordinary Nahuatl.*

With this identification the last remaining problem in the aboriginal linguistics of Guatemala is solved. We may now confidently say that there was not a tribe found anywhere on its surface by the first explorers of whose linguistic affiliations we are ignorant. Every one can be assigned to its proper ethnographic group so far as this is practicable by a knowledge of its dialect.

As to the second query, whether this Nahuatl colony immigrated before or after the Conquest, we are without positive evidence. But the letter of Palacio, written in 1576, from observations extending over years previous to that date, indicates distinctly that the language of Acasaguastlan had a recognized and independent existence in his day, and, therefore, that the people who spoke it had been found in place when the Spaniards first mapped out the land.

This colony of Nahuas, which had wandered into the upper valley of the Motagua river, was probably an off-shoot from the extensive settlements which their kindred possessed on the Pacific slope in the present Department of Escuintla, some eighty or ninety English miles distant.

The Classification and Phylogeny of the Artiodactyla. By E. D. Cope.

(*Read before the American Philosophical Society, October 7, 1887.*)

This suborder is well defined, and embraces numerous forms, many of which are living. Although it includes much variety of type, the differences shade into each other so that there is considerable difficulty in expressing the natural system in form. The usual division is into the Omnivora and Ruminantia, which are, in the language of Kowalevsky, the

* The language called the "Apay" mentioned by Palacio as spoken at Acasaguastlan has been identified by Dr. Stoll as the Chorti (*Zur Ethnographie der Rep. Guatemala*, p. 106).

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Bunodonta and Selenodonta. The latter names are very expressive of the dental characteristics of the two groups (tubercle and crescent bearing), but not having priority, they have come into use as the adjectives bunodont and selenodont, to describe the types of molar crowns to which they refer. But the divisions themselves can no longer be maintained, in view of the numerous extinct forms now known to connect them. Not only do transitions occur, but they occur at different points. Thus Dichobune is the bunodont which corresponds with the selenodont Cœnotherium; and Chœropotamus corresponds in the same way with Hyopotamus, Anthracotherium standing between. If it be desirable to name the natural groups into which the families fall, names enough exist in works on the subject, but the divisions they have been applied to are not exactly in accordance with the present writer's views of their true relations. These are presented in the following table. In this work I have been much aided by the Papers of Turner and Flower, which appeared in the Proceedings of the Zoölogical Society, of London, for 1850 and 1875; and of Gill in Smithsonian Miscell. Collec. 1873.

Before presenting the tables and phylogenetic diagrams, the author wishes to make an explanation. Statements as to the phylogeny of a given group, as family, or genus, are intended to apply to them *as defined in the present paper in the tables;* in other words, the phylogenies represent the history of particular structures. There is a tendency among writers, even with some of the best, in considering questions of phylogeny, to restrict their attention to some particular species of a genus, or genus of a family, and to consider all the minor peculiarities of said species or genus, whether appropriate to the wider question before them or not. In brief, I have not attempted to present any phylogeny of species. It will be long before we have the necessary material for that.

I. Superior molars tritubercular (Pantolestoïdea).

Molars bunodont; four digits.....*Pantolestidæ.*

II. Superior molars quadritubercular with an intermediate fifth.

1. Three digits (Anoplotheroïdea).

Intermediate tubercle anterior.....*Anoplotheriidæ.*

11. Two or four digits (Anthracotheroïdea).

A. The intermediate tubercle posterior.

Four digits; molars bunodont.....*Dichobunidæ.*
Four digits; molars selenodont.....*Cœnotheriidæ.*

AA. The intermediate tubercle anterior.

Four digits; one series of V's below.....*Anthracotheriidæ.*
Two or four digits; two series of V's below.....*Xiphodontidæ.*

III. Superior molars quadritubercular, without an intermediate fifth.

A. Molars bunodont (Suoïdea).

Four digits.....*Suidæ.*
Two digits.....*Elotheriidæ.*

AA. Molars with cross-crests (Listriodontoïdea).

Premolars different from molars.....*Listriodontidæ*.

AAA. Molars selenodont (with four crescents above).

a. Inferior molars with one series of crescents (Merycopotamoïdea).

Premolars unlike molars.....*Merycopotamidæ*.

aa. Inferior molars with two series of crescents.

β. Superior premolars (except premolar four) with one crest (Cameloïdea).

γ. "Fourth premolar like molars below, with three crests above."

Two digits only (four? in Agriochœrus).....*Dichodontidæ*.

$\gamma\gamma$. Fourth premolar entirely different from molars.

δ. Navicular and cuboid bones distinct from each other.

ε. Superior incisors present.

No cannon bone; a vertebrarterial canal.....*Oreodontidæ*.

No vertebrarterial canal; no cannon bone.....*Poëbrotheriidæ*.

No vertebrarterial canal; a cannon bone.....*Protolabididæ*.

$\varepsilon\varepsilon$. No superior incisors (except incisor three).

No vertebrarterial canal; a cannon bone; superior p. m. iv with external and internal crests.....*Camelidæ*.

Like Camelidæ, but superior p. m. iv a simple cone.....*Eschatiidæ*.

$\delta\delta$. Navicular and cuboid bones coössified.

All premolars but No. iv without internal crescent.....*Tragulidæ*.

$\beta\beta$. Superior premolars 2–3–4 with internal as well as external crest; a naviculocuboid bone; no superior incisors (Boöidea).

Superior p. m. ii without internal crescent.....*Moschidæ*.

Superior p. m. ii with internal crescent.

Horns permanent, originating distinct from skull.....*Giraffidæ*.

Horns permanent, processes of the skull.....*Bovidæ*.

Horns periodically shed.....*Cervidæ*.

Of the preceding sixteen families, ten are extinct. The six families with living representatives are the Suidæ, the Tragulidæ, the Camelidæ, the Moschidæ, the Cervidæ, the Giraffidæ and the Bovidæ.* Thus none of the primary divisions, I and II, have recent representatives. But few of them in fact (some Cænotheriidæ and Anthracotheriidæ) survived the Eocene epoch. Division III is, on the other hand, characteristic of Miocene and recent time, except that some specimens of Gelocus of the Tragulidæ have been found in Upper Eocene beds. Several genera of Tragulidæ,

*Antilocapra is sometimes separated from the Bovidæ as the type of a family, because it is said to sometimes shed its horny horn-sheath. This character, were it really normal, has no significance sufficient for the establishment of a family division.

with Elotherium and Poëbrotherium and Oreodon, belong to Oligocene beds.

Tubercular or bunodont molars are of prior age to selenodont molars, phylogenetically speaking. Of the former, the tritubercular type, it has already been shown, is ancestral to the quadritubercular type. Pantolestidæ are then clearly ancestral to all known Artiodactyla, and are themselves probably the descendants of the lost Amblypoda Hyodonta, whose existence I have anticipated on hypothetical grounds. Of the remaining families which are constructed on the quadritubercular basis, there are two types, as represented in divisions II and III of the preceding table. The intermediate or fifth lobe is especially characteristic of Eocene Artiodactyla. The intermediate tubercles exist in the Pantolestidæ, and one of them is preserved in the families of division II; but in group *A* it is the posterior one, and in group *AA* it is the anterior one. In the Suidæ and Elotheriidæ, which are permanently bunodont, the intermediates are either lost or so divided as to lose their distinctive character. In Elotherium traces of both the intermediates are visible, but they are obscure. The genetic relations of the families with five lobes to those with four are supposed by Schlosser to be direct and ancestral. This looks probable in the case of the Merycopotamidæ of the latter group, which has inferior molars like those of Hyopotamus of the former group. Whether the remaining families of division III *AAA* (see table) (four-lobed) came off from the families of division II (five-lobed) is uncertain. It is probable that the fifth and sixth (or intermediate) tubercles were present in all primitive Artiodactyla, but they may have been lost, as in the Suidæ, in the bunodont stage, which gave origin to III *AAA*, so as to be wanting from the earliest four-lobed selenodont ancestors. Of the two types of II, the division *A* (Dichobunoïdea) is supposed by Schlosser to have been the ancestor of the true selenodonts (III *AAA*), but excepting in the case of Merycopotamidæ this has not yet been demonstrated. Scott suspects with reason that the quinquetubercular Protoreodon is the ancestor of the quadritubercular Oreodon.

Leaving this debatable question, I refer to the family of the Anoplotheriidæ. The remarkable structure of the feet discovered by Gervais, and shown by Schlosser to belong to this family, distinguishes it at once from all families of this and all other orders.

The second digit is well developed in both feet, and stands inwards at a strong angle to the other toes. A rudimental fifth is present in the manus, but not in the pes. The latter is therefore tridactyle. The third and fourth digits are equal in the pes, but the third exceeds the fourth in the manus, giving an entirely perissodactyle character. Some didactyle forms have been placed in this family, but this is inadmissible on ordinary taxonomic principles. The divergent inner toe is supposed to have supported a web, useful in an aquatic life. As remarked by Schlosser, the origin of the Anoplotheridæ is entirely obscure as yet, the only ancestor yet known being the Pantolestidæ. It is probable that some

unknown member of the Anthracotheroidea, which had bunodont teeth, may form one of the missing links. Cebochœrus offers the proper type of dentition, and the number of toes (four, Schlosser) is also appropriate, but whether there are any structural obstacles to its being ancestral to the Anoplotheriidæ I do not know.

Anthracotheriidæ can be properly supposed to have descended from a type of Pantolestidæ with well-developed lateral toes, by the addition of the fourth tubercle, and the loss of the posterior intermediate; while the Dichobunidæ have had the same origin, the posterior intermediate cusp being preserved. The Xiphodontidæ may be supposed to have come off from the Anthracotheriidæ by the usual process of diminishing the lateral digits and developing both sets of crescents in both superior and inferior molars. This family carried the specialization of the five tubercled type farther than any other.

The Suoïdea have come off from the Pantolestoïdea by the addition of the fourth (posterior internal) tubercle to the superior molars. Some genus with better developed lateral (second and fifth) digits than Pantolestes must have been the ancestor. Such a form will be discovered. It has been already anticipated by Schlosser.*

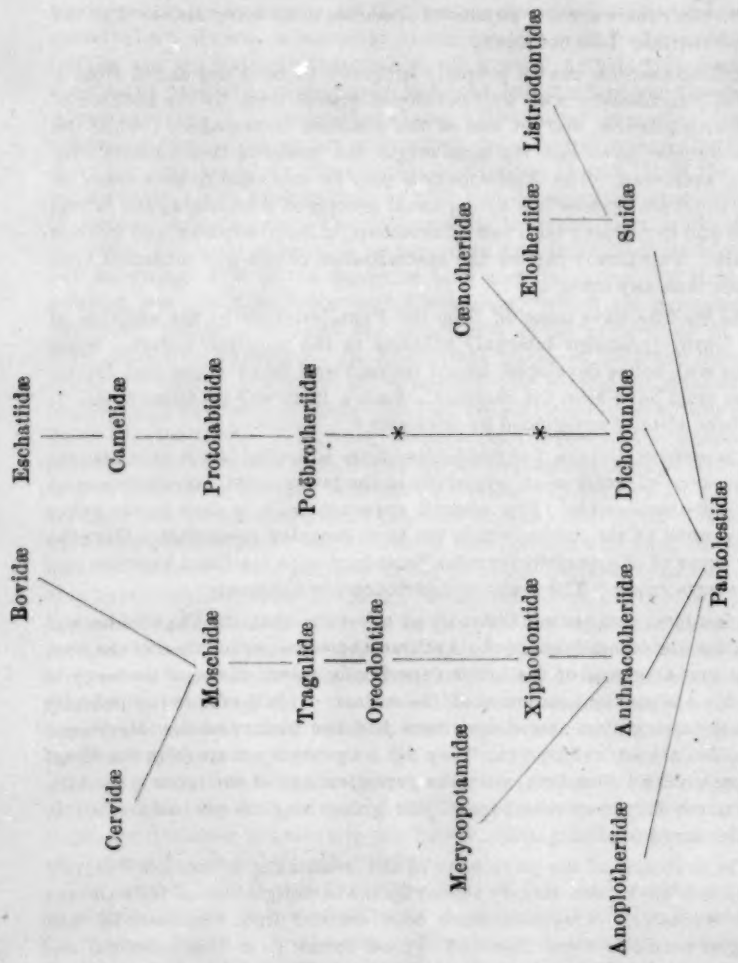
It is evident that the Listriodontidæ form a special short side-branch, with a type of molar teeth, especially in the lower series, resembling some of the Perissodactyla. The nearest approach to it is seen in the genus Platygonus of the Suidæ, which has more complex premolars. Here the four cusps of the quadritubercular bunodont type are fused together into transverse crests. The limbs of Listriodon are unknown.

It is a circumstance confirmatory of the view that the Cameloïdea and Boöïdea are descendants of the Anthracotheroïdea rather than of the Suoïdea, that no genus of the latter superfamily shows the least tendency to assume a selenodont structure of the molars. It is therefore not unlikely that the two groups named may have had the history of the Merycopotamoïdea already referred to. They did not probably come from the Merycopotamoïdea themselves, since the geological age of the latter is too late. Of course, however, members of this group may be yet discovered in earlier formations.

The problems of the phylogeny of the remaining groups are less difficult, and have been largely solved by the investigations of Kowalevsky and Schlosser. Tragulidæ have been derived from Oreodontidæ with simpler premolar teeth than the typical forms, (*e. g.* Dorcatherium and Lophiomeryx). In turn they have given origin to primitive Bovidæ (Cosoryx) through Gelocus, which have then branched off into specialized Bovidæ on the one hand, and Cervidæ on the other. The Poëbrotheriidæ have originated from some family with diminished lateral digits, perhaps the Dichobunidæ, various intermediate genera being yet unknown. They

* Morphologisches Jahrbuch, 1886, p. 77.

are the direct ancestors of the Protolabididæ, the camels, and the Eschatiidæ. These relations may be expressed in the following table:



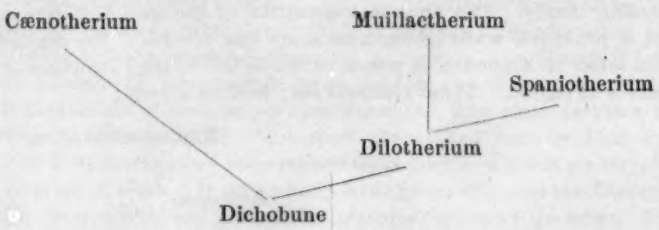
Of PANTOLESTIDÆ but one genus is known. The premolars are all simple in the upper jaw, except the fourth, which has one external and one internal tubercle.

The structure of the premolars in Anoplotherium is complex for so primitive a type, and the third superior has an internal crest as well developed as in some of the Boöïdea. To the ANOPLOTHERIIDÆ are referred, besides Anoplotherium, Diplobune of Fraas and Dacrytherium, Mixto-

therium and Mixochœrus of Filhol. But the structure of the feet of the latter genera is unknown. In Mixtotherium the fourth premolar is more, and the others less complex than in Anoplotherium.

The known genera of DICHOBUNIDÆ are Dichobune of Cuvier, with Spaniotherium and Dilotherium of Filhol, in which the intermediate tubercles are less developed than in Dichobune. They are related to the two selenodont genera of CÆNOTHERIIDÆ, Cænotherium and Muillactherium. The latter differs from the former in the absence of the intermediate crescent from the last superior molars. The species of Cænotherium differ in the absence or presence of a short diastema in the dental series, and in its position in the lower jaw, whether behind the first or second premolar.

The Dichobunid bunodont genera are ancestral to the Cænotheriid selenodont genera in the following fashion :

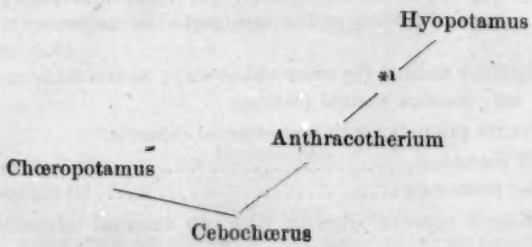


This family terminated with the selenodont genera, which, as Schlosser remarks, left no known descendants.

The ANTHRACOTHERIIDÆ present but few variations. Four genera are known, which differ as follows :

Entirely bunodont ; no diastemata ; canines developed. *Cebochœrus* Gerv.
Cusps of superior molars little flattened ; diastemata ; canines large *Chœropotamus* Cuv.
Cusps of superior molars flattened ; no diastemata ; canines large *Anthracotherium* Cuv.
Cusps of superior molars crescentoid in section ; diastemata ; canines large in males..... *Hyopotamus* Owen.

The three genera last named cannot, as Schlosser remarks, be related in direct lines, but through common ancestors ; as may be shown thus :



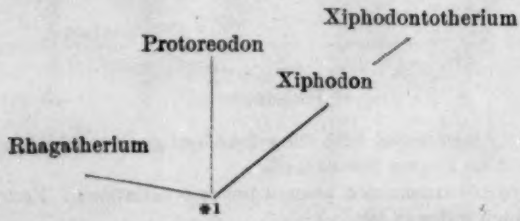
The ancestral genus is bunodont, without diastemata, and with well-developed canines. The hypothetical genus (1) is selenodont, with short diastema, and well-developed canines.

The certainly known genera of the XIPHODONTIDÆ are four, which differ as follows:

Molars bunodont; diastemata; canines large.....*Rhagatherium* Pict.
Molars selenodont; diastemata; canines medium. *Xiphodontotherium* Filh.
Molars selenodont; no diastemata; canines not distinct in form
Xiphodon Cuv.
Molars selenodont; no diastemata; superior canine developed; inferior p. m. 1 functioning as canine.....*Protoreodon* S. & O.

Cryptomeryx Schl. probably belongs here.

The relations of these genera are clearly somewhat like those of the preceding family. The bunodont condition of the molars of Rhagatherium is primitive, while its diastemata are the reverse. The continuous dental series of Xiphodon is primitive, while the detailed structure of the molars is advanced. These relations may be thus shown:



The hypothetical genus 1 is simply a bunodont without diastemata, and with well-developed canines.

The pigs, SUIDÆ, are an old family, although no genus is known prior to Miocene time. The genera present considerable variety among themselves, but some of the existing genera differ very little from some of the earliest. The greatest diversity is seen in the modifications of the incisor and canine teeth. The following represents the characters:

I. Metapodials fused proximally (Dicotylinæ).

a. Premolars like molars.

Premolars $\frac{4}{4}$; cusps of molars separate.....*Dicotyles* Cuv.
Premolars $\frac{4}{4}$; cusps of molars united into partial cross-crests
Platygonus Lec.

II. Metapodials distinct (in some unknown); molars without cementum; incisors normal (Suinæ).

a. Fourth premolar with one external tubercle.

Four superior premolars.....*Thinohyus* Marsh.
Three superior premolars.....*Chœnohyus* Cope.

aa. Fourth superior premolar with two external tubercles.

β. Superior canines decurved.

Superior canines small.....*Hyotherium* Von Myer.

$\beta\beta$. Superior canines recurved.

Molars with four much plicate tubercles on each..*Hippohyus* Cautl. Falc.

Molars with numerous irregular accessory lobes; premolars $\frac{4}{4}$..*Sus* Linn.

No accessory lobes; premolars $\frac{3}{3}$.....*Babirussa* Cuv.

III. Metapodials distinct; superior incisors reduced in number; molars reduced in number, and the valleys filled with cement (Phacochœrinæ).

Superior incisors one; premolars none; molars $\frac{3}{3}$, with numerous tubercles; superior canines recurved.....*Phacochœrus* Cuv.

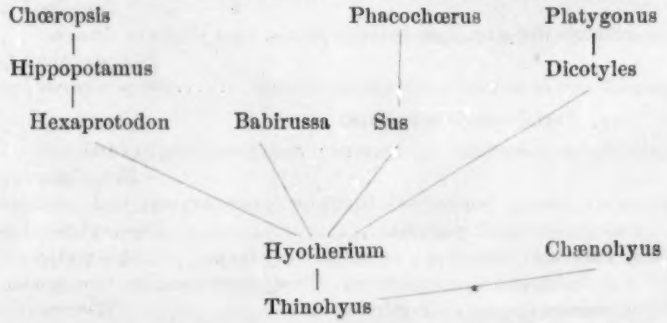
IV. Metapodials distinct, distally keeled behind only; inferior incisors straight, subcylindric (Hippopotaminæ).

Six lower incisors; orbit closed.....*Hexaprotodon* Caut. Falc.

Four lower incisors; orbit closed.....*Hippopotamus* Linn.

Two lower incisors; orbit not closed.....*Chœropsis* Leidy.

The absence of intermediate types renders the determination of the phylogeny of the genera as yet impracticable. The main features may however be foreshadowed. The most generalized form is Thinohyus, since its dentition is in all respects the most simple, while it preserves the full number of teeth. It may readily have given origin to the Dicotyline line on the one side, and Sus and its immediate allies on the other. Babirussa is another derivative from the same center. Phacochœrus may have come from some ally of Sus, since it carries to a great extreme the peculiarities of the latter genus. The ancestry of Hippopotamus is less easily determined. Its imperfect distal metapodial keels, which only exist on the posterior face of the condyle, bespeak for it an ancient ancestor. Its molar type is merely a complication of the quadritubercular, while the characters of its canines are an exaggeration of those of the primitive forms already mentioned. Several other genera, as Dicotyles and Sus, display the decumbent incisors which prepare the way for the remarkable straight digging incisors of Hippopotamus. The genus Chœropsis eases the passage backwards. These relations may be expressed as follows:



PROC. AMER. PHILOS. SOC. XXIV. 126. 2W. PRINTED DEC. 3, 1887.

But one genus of ELOTHERIIDÆ is known. The character of the feet, reduced to but two metapodials in a bunodont genus of the Lower Miocene or Oligocene, surprised Kowalevsky, who first determined the fact, and has excited similar feelings in other naturalists. But the precocious diminution of the lateral digits has been already observed in various primitive genera, as Pantolestes and Dichobune, and from one or perhaps both of these forms Elotherium was derived. In its dental characters it is of the simple suilline type. The type early ceased to exist, its latest forms being American, and some of them rivaled the rhinoceroses in dimensions.

The LISTRIODONTIDÆ and MERYCOPOTAMIDÆ include but one genus each, though others probably will be discovered. I therefore turn to the OREODONTIDÆ which embraces a larger number of forms. Its characters are as follows:

Dentition: superior incisors present; molars selenodont. Cervicals with the transverse processes perforated by the vertebrarterial canal. No alisphenoid canal. Ulna and radius, and tibia and fibula distinct. Metapodial bones four on each foot, with incomplete distal trochlear keels. Lunar bone not supported by magnum. Navicular and cuboid bones distinct. The details of the structure express various affinities. The axis is intermediate between that of the suilline and ruminant Artiodactyla; the other cervicals are suilline, while the remaining vertebræ are ruminant. The scapula is ruminant, not suilline; while the humerus is like Anoplotherium. The radiocarpal articulation is intermediate between that of hogs and ruminants. The unciform supports the lunar bone. The sacrum is ruminant, the ilium suilline. The femur and tarsus are much like those of the peccary.

The known genera of this family are the following:

A. Orbit complete; premolars four, the fourth with one external crescent. First premolar below functioning as canine.

a. No facial vacuities.

Premaxillaries distinct; otic bullæ not inflated; five digits in manus *Oreodon* Leidy.

Premaxillaries distinct; otic bullæ inflated; four digits in manus *Eucrotaphus* Leidy.

Premaxillaries coössified; otic bullæ inflated..... *Merycochœrus* Leidy.

aa. Facial vacuities present.

Premaxillaries coössified, dentigerous; vacuities prelachrymal only *Merychyus* Leidy.

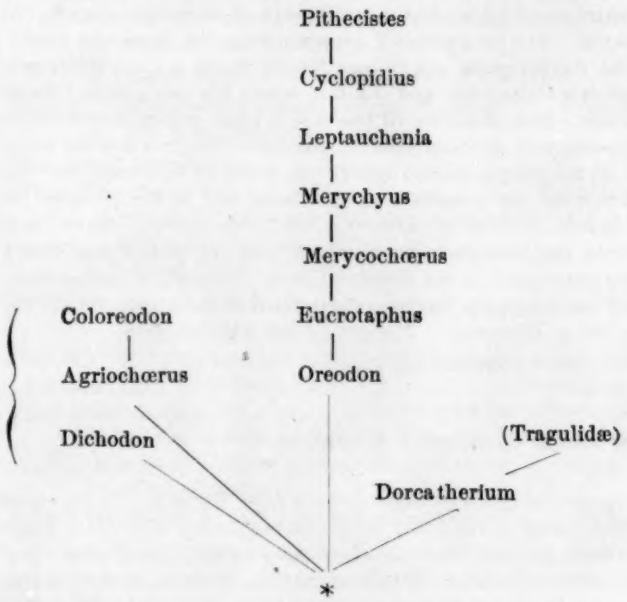
Incisors six above, persistent; vacuities prelachrymal and prefrontal; nasal bones much reduced..... *Leptauchenia* Leidy.

Incisors very few, caducous; vacuities very large..... *Cyclopidius* Cope.

AA. Inferior premolars three. True inferior canine functional.

Inferior incisors one on each side..... *Pithecistes* Cope.

Starting from Oreodon as the ancestral form, Eucrotaphus follows at a little distance. The presence of the pollex observed by Scott in Oreodon proves that it must be referred to a five-toed common ancestor with Dorcatherium. The enlarged bullæ are added in Eucrotaphus, and the coössified premaxillaries in Merycochœrus and Merychyus. The latter commences the facial vacuities, which reach such huge proportions in Leptauchenia and Cyclopidius. The loss of the incisor teeth from both jaws, and diminished size, indicate that decadence is going on in Cyclopidius, but the last term is reached in Pithecistes. Here not only incisors but a premolar disappears. This family, once powerful in numbers, size and strength, disappeared with the Upper Miocene period in North America. These relations may be thus displayed. A common ancestor with Dorcatherium is assumed. This will be a genus like Protoreodon S. & O., but without the caniniform inferior p. m. i of that genus, and probably with the fifth crescent of the superior molars. Agriochœrus may have been derived from the same.



The geological positions of these genera are as follows:

Oreodontinæ.	No. of Species.	White River Epoch.	John Day Epoch.	Tiholeptus Epoch.	Loup Fork Epoch.
Oreodon Leidy	3	———			
Eucrotaphus Leidy	3	———	———		
Merycochœrus Leidy	8		———	———	
Merychyus Leidy	6			———	———
Leptauchenia Leidy	3			———	
Cyclopidius Cope	2			———	
Pithecistes Cope	3			———	

The DICHODONTIDÆ are allied to the Oreodontidæ and Tragulidæ in the simple form of the premolars, excepting the fourth in both jaws. These resemble, according to Schlosser,* the milk teeth of other ruminants in the genus Dichodon. For the present I associate with this European genus, the American Agriochœrus and Coloreodon, in which the last lower premolar resembles a true molar, and the last upper has two external Vs as in a true molar. The structure of the feet in these genera is unknown, but in Dichodon they are supposed to consist of the two median digits only, which do not form a cannon bone.† It is safe to conclude that the American forms do not possess a cannon bone, and as the presence or absence of lateral digits is not always a family character, I leave them provisionally in the Dichodontidæ to which they are in any case nearly allied. They agree also in the resemblance of the inferior canine to an incisor tooth, but the first premolar is caniniform in the American genera, which it is not in Dichodon. The genera differ as follows:

I. First inferior premolar caniniform.

Premolars three ..... *Coloreodon* Cope.

Premolars four ..... *Agriochœrus* Leidy.

II. First inferior premolar not caniniform.

Premolars four ..... *Dichodon* Owen.

In this instance the genus of more modern type, Dichodon, is the oldest in time (Upper Eocene), the other genera being Lower Miocene. These types have been derived from some common ancestor of the family of Oreodontidæ as here defined. Dichodon may be a descendant of Lophiomeryx, and Agriochœrus be derived from an ancestor in common with that genus and Dorcatherium (for diagram see under Oreodontidæ).

The TRAGULIDÆ has a good many extinct genera, and the genus Tragulus is represented by several living species. It is difficult to separate this family from the Oreodontidæ, and the only character which appears to be

* Beiträge z. Kenntniss d. Stammesgeschichte d. Hufthiere u. Versuch einer System der Paar- u. Unpaarhufer. Morphologisches Jahrbuch, 1886, p. 56.

† The Diplopus of Kowalevsky is supposed to be Dichodon, by Schlosser.

available is the development of a naviculocuboid bone in the posterior foot. If this character be not used, then the two families will form a single natural division. This definition includes in the Tragulidæ the Gelocidæ of Schlosser, a result inevitable on any exact system. The genera remaining, of which the limb structure is known, are defined as below. Several other genera are known from teeth, as Micromeryx, Phaneromeryx, Rutitherium, etc., but since their feet are not described, I am compelled to omit them.

I. Both metatarsals and metacarpals distinct; molars brachyodont (Hypertragulinæ).

a. Lateral toes behind.

Anterior internal crescent of inferior molars represented by a conical cusp.....*Lophiomeryx* Pom.

Interior crescents of inferior molars developed.....*Dorcatherium* Kaup.

aa. No lateral toes behind.

Diastemata in both jaws.....*Hypertragulus* Cope.

II. Metatarsals forming a cannon bone; metacarpals distinct; molars brachyodont (Gelocinæ).

a. Lateral digits of the manus, none of the pes.

Superior premolars with a small internal tubercle.....*Leptomeryx* Leidy.

aa. No lateral digits.

Four lower premolars.....*Gelocus* Aym.

Three lower premolars.....*Bachitherium* Filhol.

III. A metatarsal cannon bone; metacarpals forming a cannon bone; molars brachyodont (Tragulinæ).

a. Lateral digits well developed.

Premolars entirely simple.....*Tragulus* Briss.

aa. Lateral digits weak.

Four inferior premolars, the posterior with branch ridges; superior premolar 3 with strong cingulum.....*Amphitragulus* Pomel.

Three inferior premolars, the posterior with branch ridges; superior premolar 3 with strong cingulum, elongate.*Prodremotherium* Filhol.

IV. Metatarsals and metacarpals unknown; molars hypsodont (Hypisodontinæ).

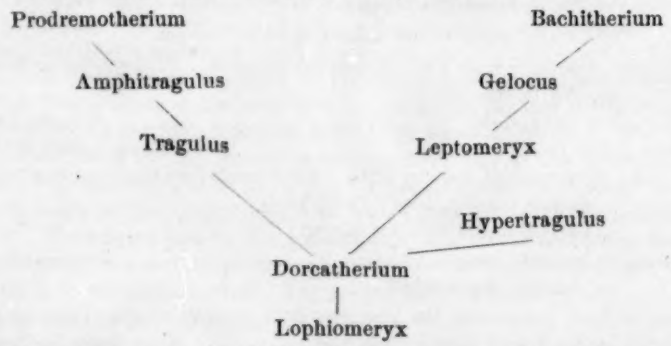
A diastema behind p. m. 2; canines not distinct.....*Hypisodus* Cope.

Of these genera, those with the metatarsals separate, and the simplest premolar teeth, must be the most primitive and nearest the Oreodontidæ.

Dorcatherium, also an existing genus, has four well-developed digits, and is nearest the Oreodontidæ. The only difference between that family and the present one being the presence and absence of the naviculocuboid bone respectively, Dorcatherium must be placed on the Tragulid side of the line. Probably extinct genera will be found which will connect this genus more intimately with the Oreodontidæ, for the slight complication of the premolars of the extinct genera of the latter, testify to earlier members with simpler ones. Lophiomeryx and

Hypertragulus must be associated with Dorcatherium on account of the lack of cannon bone. Lophiomeryx has an inferior type of inferior true molar, and like Dorcatherium has four toes on all the feet. Hypertragulus displays greater specialization in the absence of lateral digits from the posterior feet. The ulna is also coössified with the radius, and there is a naviculocuboid bone. The premolar teeth are nevertheless very simple, and are separated by diastemata in both jaws. It must be regarded as a modified descendant of Dorcatherium on one side of the main line of descent.

In the next group the metatarsals have united while the metacarpals remain separate. This is the case in Leptomeryx of the American Oligocene. In Tragulus the premolars are much simpler than those of the other genera of Section III, and simpler than those of Leptomeryx, so that these two forms must have been derived from an ancestor which combined the simplicity of both forms. For this we must again recur to Dorcatherium, and I therefore insert this genus at the base of the following diagram. With its entirely prismatic molars Hypisodus has one element of superiority, but the number of its superior premolars is unknown.



Of the POËBROTHERIIDÆ there are two genera. These differ as follows:

First premolar of upper jaw elongate and with two roots
Poëbrotherium Leidy.

First upper premolar short and with a simple conic root
Gomphotherium Cope.

The phylogenetic relations of these genera correspond with their relative geological positions. In Gomphotherium from the John Day (Middle) Miocene, the first premolar is much reduced, probably soon to be aborted, as is the case in later genera of the line, among the Camelidæ. In Poëbrotherium it displays an unusual development, like that of some Tragulidæ.

With the Poëbrotheriidæ we commence a series of families characterized by the absence of the vertebrarterial canal, or the line of the camels proper.

The direct connection with the families previously described is not yet known. The indications point to the Oreodontidæ, but no approach to the cervical vertebræ of the Poëbrotheriidæ has yet been found in that family.

Messrs. Scott and Osborn have described a mammal, from the Bridger Eocene of Wyoming, as a probable member of the camel series, under the name of *Ithygrammodon cameloides*. It is only known from two premaxillary and a part of one maxillary bones. The former are slender and bear a complete set of incisor teeth, which are followed by a large canine. It is probable that this genus belongs in the camel series, but it cannot yet be positively affirmed.

Ancestral to the Camelidæ is the genus Protolabis Cope, which agrees with Procamelus, the earliest genus of that family in most respects, but differs decidedly in having a full set of superior incisor teeth. In this genus we reach the stage, in tracing back the ancestry of the camels, which we find represented by Oreodon, or the Gelocus in the line of the cattle and deer. It is probable, though not certain, that in Protolabis the metapodial bones are combined into a cannon bone as in the Camelidæ. If so it differs materially from its predecessor, the genus Poëbrotherium, and must be regarded as the type of a special family, the PROTOLABIDIDÆ. But one genus of this family is known up to the present time. Its remains occur in the Ticholeptus beds of Oregon and the Loup Fork beds of Nebraska and Kansas.

In the CAMELIDÆ we begin to realize the characters of the latest Artiodactyla, the ruminants. But they differ from the typical forms of these, the Boöïdea, in three important points of the osteology, viz., in the absence of a canal of the cervical vertebræ which in other Mammalia encloses the vertebral artery; the presence of an incisor tooth on each side of the upper jaw; and thirdly, the incompleteness of the keels of the distal ends of the metapodial bones. This character and that of the presence of incisors, are primitive conditions common to all the early Mammalia. The peculiar cervical vertebræ constitute a specialization, but whether degenerate or progressive remains to be ascertained. In one respect this line exhibits a high specialization, which is present at the earliest known period of its history. This consists in the reduction of the lateral (II and V) metapodial bones, so that but two functional toes remain. This condition has been reached by the more typical artiodactyles after a much longer lapse of time, for most of the extinct and recent types display lateral digits in a well-developed or rudimentary condition; in but few of them have they totally disappeared. In another respect the line of the camels attains a higher specialization than that of the typical ruminants, although its beginning is that which is common to the entire suborder. This is in the dentition. The reduction in numbers of teeth shown by Owen to characterize the historical succession of all Mammalia, is carried further in the molar series of camels than in any hoofed order; for in the final term or genus, Eschatius (Cope), there is but one premolar left in the upper jaw, and that is reduced to a simple cone. The true molars never

reach the complexity of those of the other line, of the Bovidæ or oxen, nor do they become prismatic as in that family, but retain the short crown well distinguished from long roots, which belongs to all the earlier Mammalia.

The successional reduction in the numbers of premolar teeth in the family of the Camelidæ is shown in the following table.* There is seen in the genera Protauchenia and Palauchenia a tendency to an increase of complication of the fourth inferior premolar:

I. Premolar teeth $\frac{4}{4}$.

Premolar 1 separated by diastema.....*Procamelus* Leidy.

II. Premolar teeth $\frac{4}{3}$.

Premolar 11 below wanting.....*Pliauchenia* Cope.

III. Premolar teeth $\frac{3}{3}$.

Fourth inferior premolar triangular.....*Camelus* Linn.

Fourth inferior premolar composed of two crescents, which enclose a lake (an inferior premolar three?).....*Palauchenia* Owen.

Fourth inferior premolar composed of two crescents, with two posterior tubercles behind them.....*Protauchenia* Branco.

IV. Premolar teeth $\frac{2}{3}$.

Fourth premolar below triangular.....*Auchenia* Illiger.

V. Premolar teeth $\frac{1}{1}$.

Fourth superior premolar composed of two crescents..*Holomeniscus* Cope.

The only genera which include existing species are Camelus and Auchenia, the camels and llamas respectively. It may be remarked that the latter genus, which is confined to the new world, is more specialized than Camelus, which is restricted to the old world.

The succession of these genera in connection with the two preceding families, may be presented as follows:

	No cannon bone.	Cannon bone present.		
	Incisor teeth present.	Incisors one and two wanting.		
	4 premolars.	3 prem's.†	2 prem's.	1 prem'r.
Lower Miocene	*Gomphotherium*			
Upper Miocene	*Protolabis*			
	Procamelus			
		Pliauchenia		
Pliocene and recent			*Camelus*	
				Auchenia

This table shows that geological time has witnessed, in the history of

* From Proceedings Amer. Philosoph. Soc., 1884, p. 16.
† In lower jaw.

the Camelidæ, the consolidation of the bones of the feet and a great reduction in the numbers of the incisor and premolar teeth. The embryonic history of these parts is as follows: In the fœtal state all the Ruminantia (to which the camels belong) have the cannon bones divided as in Poëbrotherium; they exhibit also incisor teeth, as in that genus and Protolabis. Very young recent camels have the additional premolar of Pliauchenia. They shed this tooth at an early period, but very rarely a camel is found in which the tooth persists. The anterior premolar of the normal Camelus is in like manner found in the young llama (Auchenia), but is shed long before the animal attains maturity. I may add that in some species of Procamelus caducous scales of enamel and dentine in shallow cavities represent the incisor dentition of Protolabis.

In greater detail, the extinct American forms of this line are distributed as follows:

	Eocene.		Miocene.				Pliocene.
	Wasatch.	Bridger	White River.	John Day.	Ticholeptus.	Loup Fork.	Equus.
Pantolestes Cope....	5	1					
Ithygrammodon S. O.		1					
? Stibarus Cope.....			1				
Poëbrotherium Leidy			2				
Gomphotherium Cope				1			
Protolabis Cope.....					1	2	
Procamelus Leidy...						6	
Pliauchenia Cope....						2	
Holmeniscus Cope...							3
Eschatius Cope.....							2

The total number of genera, nine; of species, twenty-six.

The development of the brain displays the same progress that has been shown by Lartet and Marsh to have taken place in other lines of Mammalia. The figures which I have given of the brain, show that while *Procamelus occidentalis* is inferior to the camel in the size and development of the convolutions of the hemispheres, it is in advance of the *Poëbrotherium vilsoni* in these respects.

The development of the camels in North America presents a remarkable parallel to that of the horses. The ancestors of both lines appear together in the Wasatch or lowest Eocene, and the successive forms develop side by side in all the succeeding formations. Camels and horses are standard types in all our Tertiary formations; and they must be learned by any one who wishes to distinguish readily the horizons one from the other. The horse-forms are more numerous in all the beds, in individuals as well as in species. Both lines died out in North America, and of the two, the camels only have certainly held their own in South America. The history of the succession of horses in Europe, although not as complete as that in America, extends over as wide a period of time.

PROC. AMER. PHILOS. SOC. XXIV. 126. 2x. PRINTED DEC. 3, 1887.

Not so with the camels. There is no evidence of the existence of the camel line in the old world prior to the late Miocene epoch; and so far as the existing evidence goes, the new world furnished the camel to the old.

Camelidæ only appear in South American palæontology in the genus Auchenia, in Pliocene time, in the Pampean beds. The best known species are *Auchenia weddellii* and *A. intermedia* of Gervais. It is curious that M. Ameghino, in his report on the fauna of the Miocene age found on the River Parana, which contains the ancestors of so many Pliocene genera, finds none that stand in that relation to the llamas.

The ESCHATIIDÆ includes a single genus represented by large species of North America and Mexico.

We now reach the division of the Artiodactyla, which is especially characteristic of the present period; the Boöïdea, or, as it is sometimes called, the Pecora. It embraces more numerous species than any existing division of the Ungulata, and presents considerable difficulties to the zoölogist who would represent the relations of its contents. As a division it is however well defined by the following peculiarities.

The third and generally the second superior premolar teeth possess an internal crest as well as the fourth. The inferior premolar teeth have oblique transverse crests. The keel of the distal extremity of the metapodial bones extends to the front of the condyle. The lateral metapodials are represented by their extremities only, the middle portion having disappeared. The median pair are united into a cannon bone. There are no superior incisors. The odontoid process of the axis vertebra is trough-shaped. The stomach is divided into three or four parts.

The lowest family of the series is that of the MOSCHIDÆ. In its hard parts it differs from the other Bovidæ in the simplicity of the anterior (second) superior premolar, which is without the internal crescent found in the other Boöïdea. In this respect it is intermediate between that division and the Cameloidea, where the fourth premolar only possesses the internal crescent. But two genera of Moschidæ are known, Dremotherium from the Lower Miocene of France, and the living Moschus. Both lack horns and have well-developed canine teeth. The origin of this group is clearly from the Tragulidæ, and the genus of that family which approaches nearest to it is Amphitragulus, which indeed only differs from it in dentition in the imperfection of the internal crest of the third superior premolar. In turn, Dremotherium must be regarded as ancestral to Palæomeryx, the most primitive genus of the Bovidæ.

The GIRAFFIDÆ differ (see table of families) in the mode of attachment of the horns. These are originally separate from the skull, but become attached to it like the epiphyses on the extremities of the bones of the skeleton. Their dental characters are like those of the Cervidæ and the lower Bovidæ, the molars being short crowned or brachyodont. It may be that the condition of the horns in Giraffa represents the mode of origin of the horns of the Bovidæ, and that the genus is simply to be reckoned a primitive type in that family. The specialization of the long

neck and fore legs would not exclude it from that family. It is merely an adaptation for the habit of browsing on the foliage of tall trees. In the extinct species of its single genus, Giraffa, these characters are found in a less degree than in the existing one. The most obvious distinction between the BOVIDÆ and the Cervidæ is in the differing character of the bony processes of the skull, used for offense and defense. But where horns are wanting, as is the case with some genera, these distinctions fall to the ground. The horn-type of the Bovidæ is more primitive than that of the Cervidæ, since the horny process is permanent in the former, and is shed and reproduced annually in the latter. The dental type is, however, never so specialized in the deer, as is the case with the highest genera of Bovidæ, remaining always distinctly rooted, while in Bos and some other genera of the latter they become prismatic. But the lower genera of Bovidæ do not differ from Cervidæ in this respect.

In accordance with these facts the bovine ruminants appear a little before the cervine, though authors generally refer the earliest genera to the latter division. Such are the genera Dicrocerus and Cosoryx,* which appear in the latest Miocene beds. Dicrocerus only differs from Palæomeryx in the possession of horns, which resemble those of deer, but which were, according to Schlosser, never shed, a fact which compels its location in the Bovidæ. In Cosoryx the horns have the same character in this respect, but the teeth are antelopine, or prismatic. It is clearly to be placed in the Bovidæ with Antilocapra (the prong-horn), and it is closely allied to Dicrocerus. Here we see that the point of origin of the two families was from a common ancestor, and that this ancestor was, as has been already expressed by Schlosser, the genus Palæomeryx. Nearly related to this point of departure are the Sivatherium, Bramatherium, and Hydaspidotherium. As they do not shed their horns, they cannot be referred to the Cervidæ. In their covering with the integument, Cosoryx probably possessed a character of Giraffa, which is a primitive stage of the essential character of the horns of the Bovidæ. Perhaps the retention of the primitive dermal character of this investment, instead of its metamorphosis into horn, might be regarded as a basis for a distinct family, the Cosorycidæ. But it is highly improbable that this covering remained in Sivatherium and Bramatherium, whose horns were apparently perfectly naked. It is doubtful whether all these animals can be retained as distinct from the Bovidæ, and I therefore place them in two subfamilies of that family. The Cosorycinæ, which will include Cosoryx and Blastomeryx, are characterized by the sheath of the horns being dermal; the Sivatheriinæ by the absence of any sheath whatever. The synopsis of genera will then be as follows:

I. No horns in the male.

Molars brachyodont.....*Palæomeryx*† Von Meyer.

* Leidy, Cope; Procervulus Gaudry.

† Should *P. eminens*, type of Palæomeryx, have possessed horns, as suspected by Schlosser, the generic name must take the place of Dicrocerus below, and be replaced by one of the various names which apply to hornless species.

II. Horns covered with skin (Cosorycinæ).

Teeth brachyodont; no frontal excrescence.....*Blastomeryx* Cope.

Teeth prismatic; no frontal excrescence.....*Cosoryx* Leidy.

III. Horns naked (Sivatheriinæ).

Teeth brachyodont; two pairs of horns, all separate
Sivatherium Cautl. Falc.

Teeth brachyodont; two pairs of horns; those of the anterior pair from a common base.....*Bramatherium* Cautl. Falc.

Teeth brachyodont; one pair of horns, from a single base
Hydaspitherium Lydd.

Teeth brachyodont; one pair of horns, from distinct bases
Dicrocerus Lart.

IV. Horns covered with a horny sheath; teeth hypsodont (Bovinæ).

a. No internal column of true molars.

β. No lateral ungues. (Nasal bones normal; postzygapophyses single.)

Horn-sheath furcate..... *Antilocapra* Ord.

Horn-sheath simple.....*Nanotragus* Sund.

$\beta\beta$. Lateral ungues present.

γ. Nasal bones separated from maxillary and lachrymal bones.

Horns simple, one pair.....*Sæga* Gray.

$\gamma\gamma$. Nasal bones more or less in contact with lachrymal or maxillary bones.

δ. Posterior postzygapophyses single. (Numerous species not examined.)

ϵ. Inferior premolars three.

Horns one pair.....*Antidorcas* Gray.

$\epsilon\epsilon$. Inferior premolars four.

Horns two pair.....*Tetracerus* H. Smith.

Horns one pair; last inferior molar with four columns..*Neotragus** Gray.

Horns one pair; last inferior molar with five columns....*Ovis*† H. Smith.

$\delta\delta$. Posterior postzygapophyses double.

Horns one pair; inf. mol. 3 with five columns.....*Capra* Linn.

aa. One or more superior true molars with a median internal column.

Dorsal postzygapophyses single.....*Ægocerus*‡ H. Sm.

Dorsal postzygapophyses double.....*Bos*‖ Linn.

A great number of names have been given to groups of species of the Bovinæ, especially within the limits of the genus Ovis of H. Smith. Here the various forms of sheep and antelopes have been distinguished

* *N. saltianus* type. This character is derived from authority to which I cannot now refer. I have not seen it.

† Includes the following supposed genera: Antilope, Gazella, Cervicapra, Oreotragus, Cephalophus, Strepsicerus, Damalis, Alcelaphus, Nemorrhædus, Rapicapra, Caloblepas, Haplocerus, Ovibos, Ovis, and Anoa.

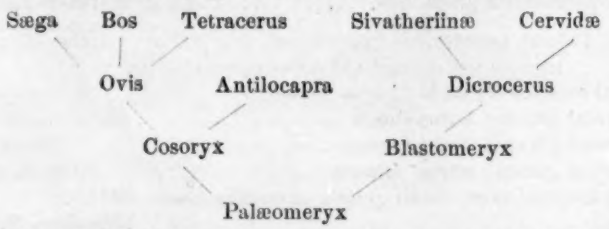
‡ Includes the following supposed genera: Eleotragus, Ægocerus, Oryx, Addax and Portax.

‖ In *Bos americanus* the postzygapophyses are single except on the last lumbar.

as genera and named accordingly. So far as concerns the skeleton, further subdivisions than those indicated in the above table do not appear to exist, and none have been pointed out. The divisions proposed appear to be rather those of one extensive genus. The modifications of the skull have reference to the position of the horns. These are processes of the frontal bones, and are placed at points from above the eye to the posterior angle of the facial plane of the skull. In the latter case this angle approaches very near to the supraoccipital crest or inion, and the parietal bone is reduced to an exceedingly narrow band between the frontal and occipital bones (Rütimeyer).* Forms with anterior horns and well-developed parietal bone are *Ovis gazella* and *Tetracerus quadricornis*, while the *Ovis gnu* displays the parietal extremely reduced, and become chiefly lateral in position. As regards the forms of the horns themselves, they present no important differences, but are angular and revolute in the section Ovis, and cylindric in the division Antilope. In the latter they vary in direction from straight to spiral or curved in different directions. Within the genus Ovis the end of the muzzle is naked or hairy, the latter in the typical forms and in those inhabiting northern and alpine localities generally. Those species that inhabit grassy or desert plains have the end of the nose naked.

Within the genus Bos modifications are observed parallel to those in the genus Ovis. The frontal bones with the horn processes are produced more and more posteriorly until the parietal bones are reduced to a narrow band across the posterior part of the skull. The bisons have the horns most anterior; then follow the buffalos, and the extreme is reached in the true oxen, of which the domesticated animal is the type.

The following table will give an idea of the phylogeny of the Bovidæ:



The hornless Palæomeryx has given origin to the horned Boöïdea; on the one hand to the brachyodont (Blastomeryx, etc.), and on the other to the hypsodonts (Cosoryx, etc.). A cornification of the integument in a fork-horned Cosoryx produced Antilocapra, while the same process in a simple-horned Cosoryx produced Ovis. The development of this type has undergone the three principal modifications indicated by the three genera which succeed upwards. In Sæga an extraordinary development of the muzzle takes place, which causes a change in the relations of the nasal bones. In Tetracerus another pair of horns is developed in front of

* Die Rinder der Tertiär-Epoche; Abh. Schweiz. Pal. Gess., v, 1878.

the usual pair. Bos develops complications of the molar teeth in both jaws.

On the brachyodont side the development of the dermal covering of the horns of Blastomeryx is arrested, and naked horned types follow. In the Sivatheriine group no further change follows except complication of the horns. In the Cervine group, on the contrary, the habit of shedding them becomes fixed, and a new family has its origin.*

Of the CERVIDÆ or the Boöïdea which shed their horns, the genus Cervus is one of the earliest with which we are acquainted. Undoubted species of the genus occur in the Pliocene, and Upper Miocene species are also referred to it. As species from the Lower Pliocene (*C. matheroni* Gerv.) are referred to Capreolus, those of the Miocene may not be true Cervi. Their structure is not sufficiently known to determine this point. The arrangement of the genera is as follows. The three primary divisions were established by Brooke.

I. Lateral metapodials complete only distally, and supporting deer claws (Telemetacarpi).

a. Nasal passages posteriorly two, separated by vomer (Cariaci)

Horns simple spikes.....*Coassus* Gray.
Horns more or less furcate.....*Cariacus* Gray.
Horns palmate.....*Rangifer* H. Smith

aa. Nasal passage posteriorly one, not divided (Capreoli).

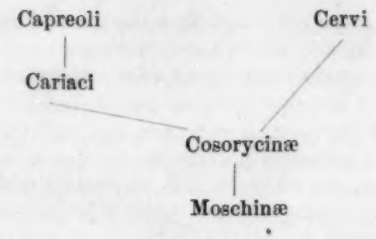
No horns.....*Hydropotes* Swinh.
Horns furcate; no postantler.....*Capreolus* Gray.
Horns palmate; no postantler.....*Alces* H. Smith.
Horns palmate; a postantler.....*Cervalces* Scott.

II. Lateral metapodials represented by proximal splints only; nasal passage not divided (Plesiometacarpi). (Cervi.)

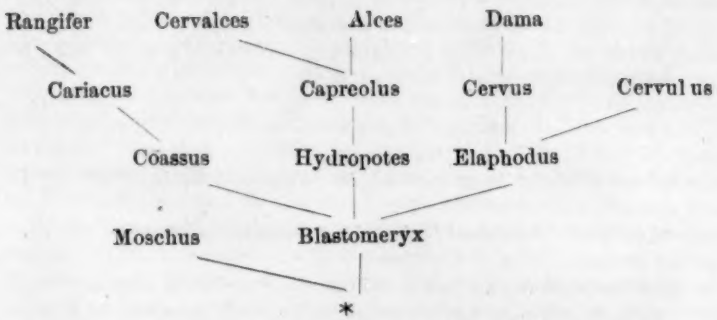
Frontal cutaneous glands; horns furcate.....*Cervulus* Blv.
No frontal glands; horns simple.....*Elaphodus* M. Edw
No frontal glands; horns furcate.....*Cervus* Linn.
No frontal glands; horns palmate.....*Dama* H. Smith.
Horns furcate; brow antler greatly exceeding beam, (Gill)
Elaphurus M. Edw.

The phylogeny of these genera cannot be fully known until the skeletons of the extinct genera and species have been obtained. It is, however, certain that the short series of genera included in each of the three divisions (II *a* and *aa*, and III), are genetic series; and also that division I is ancestral to both II and III, although perhaps by an extinct genus differing in some respects from Moschus. These relations can be thus expressed:

* I have described the probable mode of origin of the deciduous horns of the deer in Report U. S. G. Survey, W. of 100th Merid., iv, p. 348, 1877.



Or thus:



Each of the genetic series commences with a genus with no or very simple horns. The next genus or stage presents branched horns, sometimes of great complexity. The last term in each is the palmate horn, where a greater or less number of the tines unite to form a plate. These series, as is well known, correspond with the history of the growth of the horns in successive years of the life of each species.

None of the genera of this family are extinct except Cervalces Scott.

The following series may approximate a correct representation of the phylogeny of the genus Bos, expressed in genera.

Bos Ovis (sens. lat.) Cosoryx Palæomeryx	Bovidæ.
Dremotherium	Moschidæ.
Amphitragulus Gelocus Leptomeryx Dorcatherium	Tragulidæ.
*	
Anthracotherium Cebochœrus	Anthracotheriidæ.
*	
Pantolestes	Pantolestidæ.

In conclusion I would remark the fact that the gradual approaches in character to the Bovidæ by the recent and extinct genera and families, furnishes one of the most admirable illustrations of the law of progressive specialization by evolution known to me.

NOTE.—Professor Gill has presented in his system of the Mammalia some reasons why the Suidæ should be more exactly defined than I have given above. In the Suinæ and Phaochœrinæ the postglenoid process is wanting or rudimental, and the mandibular condyle is flat and triangular. In the Dicotylinæ and Hippopotaminæ the postglenoid process is well developed and the condyle is subcylindric, as is also the case in Elotherium. I therefore place the two subfamilies named in a family separate from the Suidæ, under the name Hippopotamidæ, to which it is possible that Elotherium should be united as a third subfamily.

Biographical Notice of Isaac Lea, LL.D. By Joseph Leidy, M.D., LL.D.

(*Read before the American Philosophical Society, November 18, 1887.*)

In accordance with the custom of this Society, which requires that a record shall be made of the claims of its deceased members to remembrance, at the request of our President, I have prepared a brief sketch of one who was distinguished among us, our late much respected fellow-citizen and friend, Isaac Lea, LL.D. A more detailed memoir than the one I offer seemed supererogatory from the fact that only a short time previous to his death, there was published in the Bulletins of the United States National Museum, a volume containing a Biographical Sketch of Mr. Lea, comprising fifty-nine pages; and a Bibliography of his publications with a synopsis of the material therein contained, comprising 278 pages, prepared at the request of the Smithsonian Institution, by Mr. N. P. Scudder. To this source I have conveniently applied for much of the information of my notice.

Isaac Lea was born March 4th, 1792, in Wilmington, Delaware. His grandparents, John and Hannah Lea, came from Gloucestershire, England, and accompanied William Penn in his second visit to this country. They were members of the Society of Friends, among whom they were noted as ministers. The father, James Lea, was a merchant, and at the age of fifteen Isaac went to Philadelphia to engage in a similar pursuit. In 1814, the country being at war with England, Isaac joined a volunteer rifle company, which offered its services to the Governor of the State in case of need. As the services were not required, the company was soon disbanded; but in consequence of Isaac joining it, he lost his birthright in the Society of Friends.

At an early age Isaac showed a love for natural history, in which he was encouraged by his mother, who was herself fond of botany, and in-

terested her children in its study. At an early period also he became acquainted with Lardner Vanuxem, who had similar tastes, and together the young men studied mineralogy and geology, in the pursuit of which they made frequent excursions.

In 1815 Mr. Lea was elected a member of the Academy of Natural Sciences of Philadelphia, which had been founded only three years previously. He subsequently from time to time took an active part in the affairs of the institution; and from his ample pecuniary means he liberally contributed towards its objects in the promotion of natural history. From 1853 to 1858 he occupied the position of President of the Academy. In 1817 he published in the Journal of the Academy the first of his numerous communications on natural history, entitled "An account of the minerals at present known to exist in the vicinity of Philadelphia."

In 1821 Mr. Lea was married to Miss Frances A. Carey, an accomplished lady, the daughter of Mathew Carey, a well-known publisher and a writer on political economy. He also became a member of the firm of M. Carey & Sons, which at that time was the most extensive publishing house in the United States; and he continued with this and the successive firms until he retired from the business in 1851. Mr. Scudder remarks that few men have been more happy in their married life, which reached through fifty-two years, when the death of Mrs. Lea occurred, leaving her greatly afflicted husband together with two sons and a daughter.

In 1828 Mr. Lea was elected a member of the American Philosophical Society, in which for many years he took an active part; for some time serving as one of its Vice-Presidents and as Chairman of the Publication and Finance Committee.

In the spring of 1832, together with his family, he went to Europe and visited England, France and Switzerland; returning the following autumn. In June, 1852, in company with his wife, daughter and sister, he again went to Europe, visited England, France, Germany, Austria and Italy, and returned in November, 1853. In these trips, while taking advantage of the opportunity to examine and study the favorite subjects of his special research in the great museums, he was everywhere received with the most friendly attention by eminent naturalists and others.

In 1852 Harvard University honored Mr. Lea with the title of LL.D. In 1860 he presided at the meeting of the American Association for the Advancement of Science, held at Buffalo, N. Y. As an evidence of his continued interest in all that concerns the cause of natural science, when upwards of ninety-two years of age, at the meeting of the Association and its guests of the British Association in Philadelphia, in September, 1884, he invited the members to visit him at his summer residence at Long Branch, N. J., where he had the pleasure of receiving and entertaining about two hundred.

Mr. Lea, as usual with men of distinction who have made themselves known by their scientific labors, was enrolled as an associate in numerous learned societies abroad and at home.

PROC. AMER. PHILOS. SOC. XXIV. 126. 2Y. PRINTED DEC. 6, 1887.

He reached the advanced age, within a few months, of ninety-five years, retaining to the last his intellect and his interest in his family, in science and everything that had rendered him happy during life. He died December 8th, 1886.

Mr. Lea was an enthusiastic student and an ardent lover of nature, and though like most other people occupied for many of the best years of his life with the exacting cares of business, he always found leisure successfully to pursue his studies and investigations in natural history. He was especially interested in mineralogy, geology and palæontology, but above all delighted in and devoted most time to the study of the fresh-water Mollusca, for which a favorable opportunity was afforded in the fact that the great rivers of this country are particularly rich in these animals and had been but imperfectly explored at the time of his taking up the study.

To all the subjects indicated and to others Mr. Lea has contributed to our knowledge; but to the last one in an eminent degree not excelled by other naturalists. The record of this knowledge is contained in numerous communications, for the most part published in the Transactions of the American Philosophical Society and the Journal of the Academy of Natural Sciences of Philadelphia. Mr. Lea was a most acute and accurate observer and a most painstaking and conscientious investigator. Of the fresh-water and terrestrial Mollusca, Mr. Lea has described upwards of sixteen hundred new species of about fifty genera. The descriptions are given in the most comprehensive manner with exhaustive detail, and are accompanied with admirable illustrations. He was enabled to make this large contribution to our knowledge from the fact that his name became everywhere known as the leading authority in this department of conchology, and collectors in every land eagerly submitted to him all specimens supposed to be new or otherwise of scientific interest which came into their hands.

Of Mr. Lea's labors relating to the extensive family of fresh-water Mollusca, the Unionidæ, Prof. Owen, of England, has expressed himself in the following words: "You have set a noble example of persevering devotion to the elucidation and making known to your fellow-men, of the portion of God's creation selected by your judgment, taste and opportunities for your studies. You will leave a grand and enduring monument of what one man may accomplish under such conditions, and I trust you may enjoy many years cheered by the retrospect of past labors, and by the grateful estimation in which they are held by the naturalists and lovers of science in both hemispheres."

Mr. Lea's chief contributions to geology and palæontology are found in the following works:

Contributions to Geology. 8vo. Philadelphia, 1833; 227 pages and 228 figures. This is one of the earliest and most extensive contributions to a knowledge of the geology and fossils of the Tertiary formations of this country. The work relates to the formations of Alabama, Maryland

and New Jersey, and contains descriptions of two hundred and twenty-eight new species of fossil Mollusca, together with a few other fossils.

Notice of the Oolitic Formation in America, with descriptions of some of its Organic Remains. Published in the Transactions of this Society in 1841. It relates to the formation in New Grenada and Cuba, and contains descriptions and figures of upwards of twenty new species of Ammonites, Trigonia, Terebratula, etc.

On Fossil Footmarks in the Red Sandstone of Pottsville, Pa., published in the Transactions of this Society in 1852. An earlier notice is given in the Proceedings of 1849. In this is described the tracks of an amphibian vertebrate to which Mr. Lea gave the name of *Sauropus primævus*. The fossil was discovered by Mr. Lea in the Red Sandstone of Formation No. 11, below the Coal Measures, of Roger's plan, of the Geological Survey of Pennsylvania. The report of the discovery at the time excited considerable interest among naturalists from the circumstance that the specimen was the earliest evidence of the existence of air-breathing vertebrates.

Description of a Fossil Saurian of the New Red Sandstone Formation of Pennsylvania. Published with illustrations in the Journal of the Academy in 1852. This gives a description of a saurian reptile to which Mr. Lea gave the name of *Clepysaurus pennsylvanicus*, based on some fossil bones discovered at Milford, Lehigh county, Pa., the first at that time found in the Triassic formation of this country.

Mr. Lea took the advantage of his opportunities to make a full collection of the objects of his study and investigation, and this, with the exception of the collection of Tertiary fossils, which was presented to the Academy of Natural Sciences during his life-time, he has bequeathed to the National Museum at Washington, where it will be preserved for the study and admiration of future naturalists.

Stated Meeting, September 2, 1887.

Present, 9 members.

President, Mr. FRALEY, in the Chair.

Correspondence was submitted as follows:

Letters of envoy from the Madras Observatory; Physikalisch-Central-Observatorium, St. Petersburg; K. P. Akademie der Wissenschaften, and Physikalische Gesellschaft, Berlin; Académie Royale des Sciences, Lettres et Arts, Modène; Musée Guimet, Paris; Meteorological Office and Statistical Society, London; Harvard College, Cambridge, Mass.; United

States Geological Survey and Smithsonian Institution (Bureau of Ethnology), Washington; Observatorio Meteorologico Central, Mexico; California Academy of Sciences, San Francisco.

Letters of acknowledgment from the Institut Egyptien, Cairo (123, and asking for 86, 87, 88); Natural History Society, Odessa (96–123); Comité Géologique, St. Petersburg (123); Observatoire de Tashkent (96–124); Deutsche Geologische Gesellschaft, Berlin (120–123); Naturwissenschaftlicher Verein, Bremen (121–124); Naturforschende Gesellschaft, Emden (124); Prof. Dr. Paul Albrecht, Hamburg (124); Naturhistorische Gesellschaft, Nürnberg (121–123); Verein für vaterländische Naturkunde in Würtemberg, Stuttgart (117–121); Istituto Veneto d Scienze, Lettere ed Arti, Venezia (114–116); R. Academia de la Historia, Madrid (123, 124); Académie Royale des Sciences de Lisbonne (115, 116, 117); Observatorio Astronomico Nacional Mexicano, Tacubaya (124); Canadian Institute (125); Horatio Hale, Clinton, Canada; Geological Survey of Canada, Ottawa (125); Society of Natural History, Portland, Me. (125); New Hampshire Historical Society, Concord (125); Prof. C. H. Hitchcock, Hanover (125); Boston Athenæum, Society of Natural History, Historical Society, Public Library, American Academy of Arts and Sciences of Massachusetts, Messrs. S. P. Sharples, D. Humphreys Storer, Boston (125); Museum of Comparative Zoölogy, Mr. Robert N. Toppan, Cambridge (125); Free Public Library, New Bedford (125); Dr. Pliny Earle, Mr. Benj. Smith Lyman, Northampton (125); Essex Institute, Salem (125); American Antiquarian Society, Worcester (125); Rhode Island Historical Society, Franklin Society, Providence (125); Connecticut Historical Society, Hartford (125); Yale College Library, Prof. Elias Loomis, New Haven (125); New York State Library, Albany (125); Buffalo Library, Society of Natural Sciences, Buffalo (125); Dr. Edward North, Clinton, N. Y. (125); Profs. T. F. Crane, B. G. Wilder, Ithaca (125); New York Hospital, Astor Library, Historical Society, Columbia College, University of the City of New York, Prof.

John I. Stevenson, Prof. Henry M. Baird, Messrs. James Douglas, John Ericsson, New York (125); Oneida Historical Society, Utica (125); United States Military Academy, West Point (125); Messrs. J. C. Martindale, William John Potts, Camden (125); New Jersey Historical Society, Newark (125); Dr. G. H. Cook, New Brunswick (125); Prof. W. H. Green, Princeton (125); Historical Society of Pennsylvania, College of Pharmacy, Numismatic and Antiquarian Society, College of Physicians, Library Company of Philadelphia, Hon. Wm. D. Kelley, Revs. Geo. D. Boardman, Jesse Y. Burk, H. Clay Trumbull, Drs. F. A. Genth, Wm. H. Greene, G. H. Horn, W. W. Keene, Isaac Norris, Jr., C. Newlin Peirce, Ruschenberger, W. H. Wahl, Profs. John Ashhurst, Jr., F. A. Genth, Jr., S. W. Gross, H. V. Hilprecht, J. P. Lesley, John Marshall, Messrs. W. S. Baker, Edwin A. Barber, John H. Brinton, Isaac Burk, Thos. M. Cleemann, Wm. Morris Davis, Patterson DuBois, H. H. Houston, Wm. W. Jefferis, Francis Jordan, Jr., G. deB. Keim, A. E. Lehman, A. S. Letchworth, Thos. Meehan, C. Stuart Patterson, Robert Patterson, Henry Phillips, Jr., Franklin Platt, Theo. D. Rand, G. B. Roberts, L. A. Scott, Henry D. Wireman, Jos. Zentmayer, Philadelphia (125); Dr Robert H. Alison, Ardmore (125); Prof. Jas. C. Booth, Haverford College (125); Mr. P. F. Rothermel, Linfield (125); Dr. Chas. B. Dudley, Altoona (125); Rev. Jas. A. Murray, Carlisle (125); Rev. Thos. C. Porter, Prof. J. W. Moore, Easton (125); Pennsylvania State Library, Harrisburg (125); Mr. Ario Pardee, Hazleton (125); Mr. John Fulton, Johnstown (125); Linnæan Society, Lancaster (125); Mr. John F. Carll, Pleasantville (125); Messrs. P. W. Sheafer, Heber S. Thompson, Pottsville (125); Dr. F. A. Randall, Warren (125); Hon. Washington Townsend, Mr. Philip P. Sharples, West Chester (125); Wyoming Historical and Geological Society, Wilkes-Barre (125); United States Naval Institute, Annapolis (125); Maryland Institute, Prof. H. B. Adams, Baltimore (125); Smithsonian Institution (91, 93, 104, 125 and two cases of exchanges), United States Geological Survey, Signal Office, Surgeon-General's Office, United States Naval Observatory, Patent

Office, Gen. M. C. Meigs, Drs. J. S. Billings, J. H. C. Coffin, Albert S. Gatschet, Asaph Hall, C. V. Riley, Messrs. Chas. A. Schott, Wm. B. Taylor, Washington, D. C. (125); Virginia Historical Society, Richmond (125); Leander McCormick Observatory, Prof. J. W. Mallet, University of Virginia (125); Elliott Society of Sciences and Art, Charleston (125); Georgia Historical Society, Savannah (125); Prof. E. W. Claypole, Akron, O. (125); Cincinnati Observatory, Society of Natural History, Prof. J. M. Hart, Cincinnati (125); Rev. Henry S. Osborn, Oxford, O. (125); Dr. Robert Peter, Lexington, Ky. (125); Prof. J. L. Campbell, Crawfordsville, Ind. (125); Prof. Daniel Kirkwood, Bloomington, Ind. (125); Chicago Historical Society (125); Rantoul Literary Society (125); Profs. Henry S. Frieze, Alexander Winchell, Ann Arbor, Mich. (125); State Historical Society of Wisconsin, Madison (125); Kansas Historical Society, Topeka (125); University of California, Profs. John and Joseph LeConte, Berkeley (125); California Academy of Sciences, Prof. George Davidson, San Francisco, (125).

The following societies, etc., were at request placed upon the Exchange List to receive the Society's Proceedings from No. 96:

Natural History and Antiquarian Society of Penzance; Physiological Society of Berlin; Royal Library, Brussells; Verein für Erdkunde, Metz; Wagner Free Institute of Science, Philadelphia; Voigtländischer Alterthumsforschender Verein, Hohenleuben, Saxony; Linnean Society of New South Wales, Elizabeth Bay.

A letter was read in relation to a portrait of Humboldt, offered for sale to the Society, and the President was authorized to appoint a committee to ascertain what members are desirous of subscribing to the purchase of same for presentation to the Society.

The Observatorio Meteorologico Magnetico Central, Mexico, requested by letter Proceedings 102, 103, 104, 106, 107, 108, 116; on motion the request was granted.

Letters accepting membership were read from:

Dr. Henry Kiepert, Berlin.

Miss Helen C. de S. Abbott, Philadelphia.
Mr. Joseph S. Harris, Philadelphia.
Mr. William Henry Rawle, Philadelphia.
Prof. Albert H. Smyth, Philadelphia.
Prof. James Tyson, M.D., Philadelphia.
Prof. William Powell Wilson, M.D., Philadelphia.
Mr. Henry D. Wireman, Philadelphia.
Mr. Wm. T. Barnard, Baltimore, Md.

Circulars were presented as follows:

From Dr. A. de Bausset, Chicago, in relation to his proposed aerial polar voyage in June, 1888.

From the Australasian Association for the Advancement of Science, to be held November 10, 1886.

From the Academia Regia Nederlandica enclosing its Programma Certaminis Poeticæ, 1888, with award of prizes.

From the Committee on the Centennial Celebration of the settlement of the Northwest, to be held at Marietta, Ohio, April 7, 1888.

A communication was presented from Dr. Genth, enclosing corrections of some *errata* that had occurred in printing his paper.

Accessions to the Library were reported from the Asiatic Society of Japan, Yokahama; Physikalische Gesellschaft, Deutsche Geologische Gesellschaft, K. P. Akakemie der Wissenschaften, Berlin; Prof. H. Carvill Lewis, Heidelberg; K. Sächsische Gesellschaft der Wissenschaften, Leipzig; Deutsche Gesellschaft für Anthropologie, etc., Geographische Gesellschaft, München; Verein für vaterländische Naturkunde in Würtemberg, Stuttgart; Prof. F. Sandberger, Würzberg; Société Helvétique des Sciences Naturelle, Genève; Société Vandoise des Sciences Naturelle, Lausanne; Académie R. de Copenhagen; K. Zoologisch Botanisch Genootschap, 'S. Gravenhage; Société Malacologique de Belgique, Bruxelles; Académie R. des Sciences, etc., de Modena; Società Toscana di Scienze Naturali, Pisa; R. Comitato Geologico d'Italia, Roma; R. Istituto Veneto di Scienze, etc., Venezia; British Association for the Advancement of Science, Zoölogical Society, Lon-

don; Penzance Natural History and Antiquarian Society, Plymouth; Royal Dublin Society; South African Philosophical Society, Cape Town; Royal Society of Canada, Montreal; American Oriental Society, Boston; Albany Institute; Meteorological Observatory, Academy of Sciences, American Chemical Society, New York; Franklin Institute, Prof. Edwin J. Houston, Mr. Henry Phillips, Jr., Mr. E. V. d'Invilliers, Philadelphia; United States Geological Survey, United States National Museum, National Academy of Sciences, Dr. Francis Wharton, Washington, D. C.; Wisconsin Historical Society, Madison; Editor of "The American Antiquarian," Chicago; University of California, Berkeley; Deutsche Wissenschaft-Verein zu Santiago de Chili.

Photographs for the Album were received from Prof. Giuseppi Sergi, Rome; Prof. Henry M. Baird, New York; Prof. Edward North, Clinton, N. Y.; Rev. George Dana Boardman, Drs. Isaac Norris, Jr., Wm. Thomson, and Mr. Patterson DuBois, Philadelphia.

The committee to examine the paper on the *Datames Magna*, reported it worthy of publication, and was on motion discharged.

Announcement was made of the deaths of the following members:

Prof. S. F. Baird, Washington, D. C., August 19, 1887, æt. 65.

Charles Rau, Washington, D. C., July 25, 1887, æt. 61.

Jean Victor Duruy, Paris, August, 12, 1887, æt. 76.

Alvan Clark, August 22, 1887, Cambridgeport, Mass., æt. 84.

Rt. Rev. William Bacon Stevens, Philadelphia, June 11, 1888, æt. 73.

Dr. N. A. Randolph, Philadelphia, August 21, 1887, æt 30.

On motion, the President was authorized to appoint suitable persons to prepare the usual obituary notices of Dr. Randolph and Bishop Stevens. [Subsequently the President appointed Rev. Jesse Y. Burk for Bishop Stevens and Dr. Rothrock for Dr. Randolph.]

Communications were presented through the Secretaries as follows:

1. "On Biela's Comet and the Large Meteors of November 27–30," by Prof. Daniel Kirkwood, Bloomington, Ind.

2. "On the Systematic Position of the Mallophaga," by Prof. A. S. Packard, Providence, R. I.

3. "Preliminary Report on the Vertebrate Fossils of the Uinta Formation Collected by the Princeton Expedition of 1886," by Profs. W. B. Scott and Henry F. Osborn, Princeton, N. J.

Dr. D. G. Brinton read a paper entitled "Were the Toltecs an Historic Nationality?"

Pending nominations Nos. 1156, 1159, 1164, 1169 and 1170 were read.

The President reported that he had received and paid over to the Treasurer $132.11, the July interest from the Michaux legacy.

Mr. Price offered the following resolutions, which were unanimously adopted:

Resolved, That J. Sergeant Price, Treasurer, be authorized to assign and transfer unto the Board of Reconstruction Trustees of the Philadelphia & Reading Railroad Co., and The Philadelphia & Reading Coal and Iron Co., the loans of The Schuylkill Navigation Co., belonging to the American Philosophical Society and to the Trustees of the Building Fund of the American Philosophical Society, in accordance with the terms and conditions of the proposition of June 22, 1887.

Resolved, That the Treasurer be and he is hereby authorized to receive payment of one thousand dollars, of the loans of the City of Philadelphia, now standing in the name of the Society, and belonging to this Society, and maturing July 1, 1887.

And the meeting was adjourned by the President.

PROC. AMER. PHILOS. SOC. XXIV. 126. 2z. PRINTED DEC. 6, 1887.

Stated Meeting, September 16, 1887.

Present, 5 members.

President, Mr. FRALEY, in the Chair.

Letters of envoy from Société de Littérature Finnoise, Helsingfors; Voigtländischen Alterthumsforschenden Vereins, Hohenleuben; K. Sächsische Gesellschaft der Wissenschaften, Leipzig; Statistical Society, London; California Academy of Sciences, San Francisco; Observatorio Meteorológico Central, Mexico; Observatorio Nacional Argentino, Cordoba.

Accessions to the Library were reported from the Société de Littérature Finnoise, Helsingfors; Société Impériale des Naturalistes, Moscow; Comité Geologique, Académie Impériale des Sciences, St. Petersburg; Prof. G. vom Rath, Bonn; Gartenbauverein, Darmstadt; Senckenbergische Naturforschende Gesellschaft, Frankfurt a. M.; Voigtländischer Alterthumsforschender Verein, Hohenleuben; Zoologischer Anzeiger, Leipzig; Verein für Erdkunde, Metz; Académie R. de Belgique, Bruxelles; R. Accadémia dei Lincei, Rome; Société de L'Enseignement Supérieur, Paris; Philosophical and Literary Society, Leeds; Royal Cornwall Polytechnic Society, Falmouth; Royal Society, Royal Statistical, Geological, Astronomical, Meteorological Societies, Society of Antiquaries, Linnean Society, London; American Philological Association, Boston; American Antiquarian Society, Worcester; "American Journal of Science," New Haven; Historical Society, College of Pharmacy, Library Company, Publishers of "The American Naturalist," P. H. Law, Henry Phillips, Jr., Philadelphia; Johns Hopkins University, Publishers of "American Chemical Journal," "American Journal of Philology," Baltimore; United States Naval Institute, Annapolis; Bureau of the Mint, Bureau of Labor, United States Geological Survey, Smithsonian Institution, Washington, D. C.; California Academy of Sciences, San Francisco; Publishers of "Boletin de Estadistica del Puebla."

A letter was read from the Academy of Fine Arts, requesting the loan of portraits for its approaching exhibition.

On motion, it was

Resolved, That the Curators be empowered to loan to the Academy of Fine Arts, such paintings as it may desire for its *Exhibition of Historical Portraits*, taking proper guarantees for the safe keeping and safe return of the same.

A paper was presented, through the Secretaries, by Dr. A. C. Stokes, of Trenton, N. J., on some "New Fresh Water Infusoria."

Pending nominations Nos. 1156, 1159, 1164, 1169 and 1170 were read.

A communication from the Committee on Library, on the subject of modernizing the Library, was presented, and, on motion of Mr. Law, it was resolved, that the Committee on Finance be requested to incorporate into its estimates for the coming fiscal year an appropriation of five hundred dollars, to be expended in the purchase of modern works of reference and value.

On motion of Dr. Ruschenberger, the Society ordered that the building of the Society should be kept locked on September 16, 1887, to avoid danger to the property of the Society from the vast crowds likely to be assembled in Independence Square to witness the closing exercises of the Centennial Celebration of the Adoption of the Federal Constitution.

The President reported that he had appointed as the Committee on the Purchase of the Humboldt Portrait, Messrs. Philip C. Garrett, D. G. Brinton and Horace Jayne.

On motion of Mr. Phillips, the Society requested the President to prepare for the Records of the Society a minute that should commemorate the celebration that had taken place in Philadelphia, on September 15, 16, 17, 1887, of the Centennial of the Adoption of the Federal Constitution.

And the Society was adjourned by the President.

Stated Meeting, October 7, 1887.

Present, 20 members.

Vice-President, Dr. RUSCHENBERGER, in the Chair.

Dr. Tyson and Mr. Harris, newly elected members, were presented to the Chair and took their seats.

Correspondence was submitted as follows:

Letter of envoy from L'Académie R. des Sciences, Amsterdam.

Letters of acknowledgment from L'Académie R. des Sciences, Amsterdam (122, 123); Royal Society, Royal Institution, Linnæan, Royal Meteorological, Chemical, Geological Societies, London; Geological and Natural History Survey, Ottawa, Canada; Prof. O. C. Marsh, New Haven, Conn.; Prof. C. A. Young, Princeton, N. J.; Prof. C. H. F. Peters, Clinton, N. Y.; Vassar Brothers' Institute, Poughkeepsie, N. Y.; Rev. F. A. Muhlenberg, Philadelphia; Profs. Lyman B. Hall, Isaac Sharpless, Haverford, Pa.; Lackawanna Institute, Scranton, Pa.; Prof. M. H. Boyè, Coopersburg, Va.; Mr. Horatio Hale, Clinton, Ontario, Canada; Mr. Everard F. im Thurn, Pomeroon River, British Guiana (125).

Accessions to the Library were received from Government Botanic Garden, Adelaide; Prof. Clemens Winkler, Leipzig; Publishers of "Der Naturforscher," Tübingen; K. Akademie van Wetenschappen, Amsterdam; Sociètè Hollandaise des Sciences, Harlem; Osservatorio di Torino; Sociedade de Geographia, Lisboa; British Government, Meteorological Office, London; Prof. Joseph Prestwich, Oxford; Prof. H. Carvill Lewis, Manchester, Eng.; Natural History Society, Montreal, Canada; Brooklyn Entomological Society; New Jersey Historical Society, Newark; University of Pennsylvania, D. G. Brinton, William Pepper, Henry Phillips, Jr., Philadelphia; Johns Hopkins University, Baltimore; United States Fish Commission, Department of State, War Department, Hydro-

graphic Office U. S. N., Public Opinion Co., Washington, D. C.; Leander McCormick Observatory, University of Virginia; Col. Charles C. Jones, Jr., Augusta, Ga.

A photograph for the Society's Album was received from Dr. C. A. Oliver.

Prof. Cope presented a communication for the Proceedings upon the "Classification and Phylogeny of the Artiodactyla."

The Secretaries presented two communications from Mr. Samuel Garman (Cambridge, Mass.), on the "Reptiles and Batrachians of Grand Cayman" and on "West Indian Reptiles in the Museum of Comparative Zoölogy (Cambridge, Mass.)."

Pending nominations No. 1156, 1159, 1164, 1169 and 1170 were read.

A communication was read from the Committee on Library, in reference to the operation of the resolution of the Society, of January 7, 1887, and on motion of Dr. Horn, the Society resolved that the resolution of request of January 7, 1887, should be rescinded.

Mr. Ames suggested that in the absence of papers intended for the Proceedings or for the Transactions, the meetings of the Society should be enlivened and enriched by unwritten communications; that members should report the best results of their reading and reflections on subjects of science and philosophy.

Mr. Fraley, in reply to a question, described the social and conversational features of the Society's meetings after adjournment in earlier times.

Mr. Ames made reference to the recent address of the President of the British Geological Society, on "The Relations of Mind and Matter," after which a discussion ensued, participated in by Messrs. C. G. Ames, Philip H. Law and Prof. E. D. Cope.

And the Society was adjourned by the President.

Stated Meeting, October 21, 1887.

Present, 26 members.

President, Mr. FRALEY, in the Chair.

Prof. Smyth, a lately elected member, was presented to the Chair and took his seat.

Correspondence was submitted as follows:

A letter, dated September 10, 1887, from the Geographical Society of Lisbon, announcing the death of its President, M. d'Aguiar.

Letters from Prof. Joseph Prestwich and Sir Richard Owen, giving change of address.

A letter from the New York Academy of Medicine, asking exchange of publications, which on motion was granted.

A letter of envoy from the Meteorological Office, London, Eng.

Letters of acknowledgment from R. Saxon Society of Science, Leipzig (125); Philosophical Society, University Library, Cambridge, Eng. (125); Yorkshire Geological and Polytechnic Society, Halifax, Eng. (125); Royal Statistical, Society of Arts, London, Eng. (125); Zoölogical Society of London (122–125); William Crooks, Sir Richard Owen, London, Eng. (125); Sir Henry W. Acland, Oxford, Eng. (125); Society of Antiquaries of London (125); Royal Dublin Society (125); Prof. W. P. Wilson, Philadelphia (125); Col. Garrick Mallery, Washington, D. C. (125).

Accessions to the Library were received from the Linnæan Society of New South Wales, Sydney; New Zealand Institute, Wellington; Serge Nikitin, St. Petersburg; K. K. Universitäts Sternwarte, Prag; Gesellschaft für Anthropologie, Ethnologie, etc., Berlin; G. vom Rath, Bonn; Silesian Botanical Exchange Society, Planegg; K. Nordiske Oldskrift Selskab, Copenhagen; Biblioteca Nazionale Vittorio Emanuele, Rome; Société de Géographie, Paris; Meteorological Council, Cobden Club, London; American Academy of Arts and

Sciences, Boston; H. W. Conn, Middleton, Conn.; New York Academy of Sciences; Irish Benevolent Union of the United States, Rev. Charles G. Ames, Dr. Frazer, Martin I. J. Griffin, Philadelphia; Johns Hopkins University, Baltimore; University of California, Sacramento.

Pursuant to appointment, Mr. Philip C. Garrett read an obituary notice of the late Pliny Earle Chase, LL.D., a Vice-President of the Society.

This being the stated meeting for the balloting for candidates for membership, an election was held and the following persons were declared to have been duly elected members of the Society:

No. 2145. Prof. Guisèppe Menenghini, Pisà, Italy.

No. 2146. Prof. Edgar F. Smith, Springfield, Ohio.

A paper was presented, through Vice-President Ruschenberger, for the Proceedings, by Alfred B. Taylor, on "Octonary Numeration and its Application to a System of Weights and Measures."

Prof. Cope made some remarks on the "Phylogeny and Classification of the Artiodactyla;" after which Dr. J. Cheston Morris spoke of the remarkable resemblance between Devonshire sheep and goats; that both ewes and bucks had horns, and like the goat they had more than one period of reproduction in the year; that they seemed to be something between sheep and goats.

The President reported that he had received and paid over to the Treasurer the sum of $131.80, being the interest on the Michaux legacy, due October 1, 1887.

On motion of Prof. Snyder, the President was authorized to appoint a committee of three members to inquire into the scientific value of the newly invented language, *Volapük*, and to report thereon to the Society. [The President subsequently appointed Messrs. D. G. Brinton, Henry Phillips, Jr., and Monroe B. Snyder as the Committee.]

And the Society was adjourned by the President.

Stated Meeting, November 4, 1887.

Present, 16 members.

President, Mr. FRALEY, in the Chair.

Correspondence was submitted as follows:

Letters of envoy from the Meteorological office, London; New York Academy of Medicine; New York State Library.

Letters of acknowledgment from the K. K. Sternwarte in Prag (124); Anthropologische Gesellschaft, Berlin (125); Dr. Paul Albrecht, Hamburg (125); Société d'Émulation, Abbeville (125); Société de Borda, Dax (125); Professor Geikie, Edinburg (125); New York Academy of Medicine (96–125); Franklin Institute (Laws and Regulations), Mr. Charles Bullock, Philadelphia (125); Kansas Academy of Science, Topeka (125).

A photograph for the Society's Album was received from Sir Lowthian Bell, Bart., Newcastle-on-Tyne.

Accessions to the Library were received from the K. K. Geologische Reichsanstalt, K. K. Zoologisch-botanische Gesellschaft, Wien; Gesellschaft für Erdkunde, Berlin; Naturwissenschaft Gesellschaft "Isis" in Dresden; Naturforschende Gesellschaft, Emden; Naturforschende Gesellschaft, Freiburg, i. B.; Oberhessische Gesellschaft für Natur- und Heilkunde, Geissen; Oberlausitzische Gesellschaft der Wissenschaften, Görlitz; Physikalisch-Oekonomische Gesellschaft, Königsberg; Société Historique Littéraire, Artistique et Scientifique du Cher; University Library, Cambridge, Eng.; Canadian Institute, Toronto; Museum of Comparative Zoölogy, Cambridge, Mass.; Boston Society of Natural History; Academy of Medicine, State Library, Mr. Theodore Sutro, New York; Geological Survey of New Jersey, Trenton; Mercantile Library, Dr. C. M. Cresson, Mr. Henry Phillips, Jr., Philadelphia; Historical Society of Delaware, Wilmington; Society of Natural History, Cincinnati; University of California, Berkeley.

The deaths of the following members were announced:

Gustav Kirchhoff, Berlin, October 17, 1887, æt. 63.

Thomas M. Walter, Ph.D., LL.D., Philadelphia, October 30, 1887, æt. 83.

Alfred Mordecai, Philadelphia, October 23, 1887, æt. 84.

And on motion, the President was authorized to appoint suitable persons to prepare the usual obituary notices of Messrs. Walter and Mordecai. [Subsequently the President appointed Dr. Hays for Major Mordecai and Dr. Rothrock for Dr. Randolph.]

Dr. Brinton read a paper on the "so-called" *Alaguilac* language of Guatemala.

Prof. Cope made an oral communication on the mechanical causes of the structure of teeth in certain mammalia groups.

New nomination 1171 was read.

The Society authorized the President, Secretary and Treasurer to receipt for the legacy of $2000 from the estate of Henry Seybert, deceased, now ready to be paid over.

The Committee on the Purchase of the Humboldt Portrait reported progress.

An invitation to attend the lecture on "Rapid Transit in Cities," by Prof. Haupt, at the Franklin Institute, on Friday, November 11, 1887, was given to the Society.

And the Society was adjourned by the President.

Stated Meeting November 18, 1887.

Present, 31 members.

President FRALEY in the Chair.

Messrs. W. F. Norris and G. DeBenneville Keim took their seats.

Correspondence was submitted as follows: A letter from Prof. Edgar F. Smith, of Springfield, Ohio, accepting membership.

A circular from the New York Academy of Sciences, asking

contributions to a memorial monument to John James Audubon, to be erected in the city of New York.

Letters from the Geographische Gesellschaft, Munich, and also one from the Colorado Scientific Society, of Denver, requesting exchanges, which requests, on motion, were granted.

Letters of envoy from the Royal Statistical Society and Meteorological Office, London.

Letters of acknowledgment from the Royal Society of New South Wales (123); K. K. Central-Anstalt für Meteorologie und Erdmagnetismus, Wien (125); Naturforschende Gesellschaft, Emden (125); Prof. Adolph Bastian (125), and Meteorologisches Institut, Berlin (117–125, etc.); Prof. G. vom Rath, Bonn (125); Naturwissenschaftlicher Verein zu Bremen (125); K. Sternwarte, Munich (125); Société Historique Littérataire, etc., du Cher (125); Société Geologique de France, Victor Duruy and Prof. Abel Hovelacque, Paris (125); Mr. L. A. Scott, Philadelphia (125 and all previous numbers).

Accessions to the Library were reported from the Geographische Gesellschaft in München; Prof. Henri de Saussure, Genève; Prof. G. Sergi, Rome; R. Academia de la Historia, Madrid; Meteorological Council, R. Statistical Society, Sir Lowthian Bell, London; Historical Society, Commission of the State Reservation at Niagara, Buffalo; Prof. J. S. Newberry and publishers of "The Cosmopolitan," New York; Publishers of "The Medical and Surgical Reporter," and Mr. Henry Phillips, Jr., Philadelphia; Bureau of Education, Washington, D. C.; Washburn College, Kansas State Society, Topeka; Colorado Scientific Society, Denver; Observatorio Astronomico Nacional de Tacubaya, Mexico; República Argentina, America del Sud-Buenos Aires.

A photograph of Prof. F. Max Müller, of Oxford, was presented by himself for the Album of the Society.

An obituary notice of the late Isaac Lea, LL.D., by Prof. Joseph Leidy, was read.

The Proceedings of the Officers and Council were submitted, and the Clerk of the Council transmitted the Report of the

Special Committee appointed by the Society on May 20, 1887, to examine into the merits of a communication for the Magellanic Premium, signed "*Magellan*," upon "The Physical Phenomena of Harbor Entrances; Their Causes and Remedies; Defects of present Methods of Improvement," and with the same the statement that the Council approved of the recommendation that the Magellanic Premium should be awarded therefor.

A paper entitled "Notes on the Ethnology of British Columbia," by Dr. F. Boas, was presented through the Secretaries.

Dr. Brinton read a paper on "An Ancient Human Footprint from Nicaragua," of which he exhibited a specimen, and in the discussion that ensued Prof. Heilprin stated that in his opinion the deposit in which it occurred was not of the Eocene period, but was Post-pliocene.

Prof. E. F. Smith (Springfield, Ohio) presented (through the Secretaries) a paper on "Electrolysis of Lead Solutions."

Pending nomination No. 1171 and new nomination No. 1172 were read.

Prof. Edwin J. Houston made the following oral communications:

On a Non-Magnetizable Watch.

C. A. Paillard, of Geneva, Switzerland, after some fourteen years' experimentation, has succeeded in producing a watch that is entirely destitute of any magnetizable material.

The rapid growth of electric lighting and electric railways renders the magnetization of watches a matter of frequent occurrence, and the injury to the accuracy of time-pieces occasioned by inadvertently entering the magnetic field of the dynamo-electric machines, or motors producing the current, is well known.

Heretofore a magnetic shield, consisting essentially of an iron-encasing box, has been employed to protect the works of the watch against the influence of an external magnetic field. Such shields are, for the greater part, clumsy and heavy.

Mr. Paillard's invention effects the protection of the watch in a much more thorough manner, and does so without rendering it any heavier.

It will be seen that the problem Mr. Paillard set himself to solve, was

to produce an alloy or metallic substance that possesses the following properties, viz:

1st. It must be non-magnetic.

2d. It must resist rusting and oxidation.

3d. It must be permanently elastic.

These properties he has obtained in an alloy of palladium.

By the combination of two alloys containing different quantities of palladium, Mr. Paillard has succeeded in obtaining accurate compensation for changes of temperature in the balance wheels of his watches.

On the Gramophone.

Mr. Emil Berliner, of Washington, D. C., has recently made improvements in the speaking phonograph that, it would seem, will probably bring this instrument into every-day commercial use. These inventions are of such a character as, possibly, to a great extent, to render phonography, or short-hand reporting, one of the lost arts.

There have been two causes for the failure of Mr. Edison's phonograph to come into extensive use. These are briefly:

1st. The perishable nature of the phonogram record, which, being made on a sheet of tin-foil, was capable of reproducing the original sound a limited number of times only.

2d. The inability of the phonograph, as originally constructed, to correctly reproduce the sounds spoken into it. The pitch or tone was correctly reproduced, provided the point attached to the diaphragm of the receiving instrument was moved over the phonogram-record at the same velocity that it had while in the receiving instrument. The quality of the tone, on the preservation of which the ability to distinguish the speaker's voice depends, could not, however, be obtained to the extent a practical instrument demands. This arises not only from the fact that the original instrument failed to correctly impress on the phonogram-record the relative intensities of the over-tones, on which the quality depends, but also on the fact that the receiving instrument was unable, from the relative positions these impressions bore to the surface of the phonogram-record, to always correctly reproduce them.

These difficulties Mr. Berliner has, to a very great extent, overcome in an instrument called by him the gramophone.

The direction in which these improvements have been made is mainly in the manner in which the receiving diaphragm of the instrument is caused to leave an impression of its movements on the phonogram-record. In the Berliner instrument, unlike the original Edison instrument, the to-and-fro movements of the diaphragm are received by the plate in a direction parallel to its surface, and not in a direction at right angles thereto. By this change the movements are recorded as a sinuous line of even depth, instead of a sinuous line of varying depths.

It results from this difference that the resistance offered by the plate to the free movements of the transmitting diaphragm is reduced to a mini-

mum, thus permitting much greater accuracy of the record received. At the same time the point attached to the receiving diaphragm has a positive motion in both directions, and can thus more correctly reproduce the characteristic quality of the spoken words.

In any phonogram-record made in a direction at right angles to the record surface, the fact that the resistance to impression does not increase in the same proportion as the depth of the impression will prevent the record from agreeing closely with the original tones. Loud tones must therefore fail to impress their characteristic quality on the phonogram-record, as correctly as more feeble tones.

Mr. Berliner prepares his receiving surface as follows : A plate of glass is covered with a layer of printers' ink, and then held in the smoky flame of a coal oil lamp and covered with a uniform layer of soot. On the surface thus prepared the stylus or point attached to the transmitting diaphragm, makes its record of a uniform depth. It then only remains to fix the record so obtained. This is accomplished by the simple expedient of flowing the plate with any ordinary quick-drying varnish. From this plate the sound can be directly reproduced, or a copy of it can be made on any desired metal.

There are three ways in which the reproduction may be made, viz :

1st. By the simple process of mechanical engraving.

2d. By chemical deposition.

3d. By photo-engraving.

This latter process is preferred by the inventor, the chromo-gelatine process being generally adopted.

The Committee on the Michaux Legacy presented a report, accompanied by the following resolution, which was, on motion, adopted:

"*Resolved*, That the sum of $200 be expended under the supervision of the Michaux Committee, for the expenses of lectures of Prof. Rothrock, to be delivered in the Chapel of the University of Pennsylvania."

The committee appointed October 21, 1887, to examine into the scientific value of the newly invented language, Volapük, and to report thereon, presented its report, which, after discussion, was, on motion of Mr. Winsor, made the special order for the next meeting of the Society, and the Secretaries were requested to have it printed and distributed among the resident members for inspection.

And the Society was adjourned by the President.

Notes on the Ethnology of British Columbia. By Dr. F. Boas.

(Read before the American Philosophical Society, November 18, 1887.)

NOTE.—The Indian words are spelled according to the system used by the Bureau of Ethnology: q is the German ch in Bach; c is the English sh.

In the following remarks I intend to give a brief summary of the results of my journey in British Columbia. The principal purpose of my researches was to study the distribution of the native tribes, their ethnological character, and their languages. I arrived in Victoria in September, 1886, and spent most of my time among the natives of the east coast of Vancouver island and of the mainland opposite; but in the course of my journeys I came in contact with several individuals of the Tlingit, Tsimpshian, and Bilqula tribes, and I studied particularly the language of the last, of which I had obtained a slight knowledge from a number of men who were brought by Captain A. Jacobsen to Berlin. Among the linguistic results of my journey the most interesting are the discovery of three unknown dialects of the Salish stock and the establishment of the fact that the Bilqula, who are of Salish lineage, must have lived at one time with other Salish tribes near the sea.

Though the culture of these tribes seems very uniform, closer inquiry shows that they may be divided into four groups—the northern one comprising the Tlingit, Haida, and Tsimpshian; the central comprising the Kwakiutl and Bilqula; the southern comprising the different tribes of the Coast Salish; and the tribes of the west coast of Vancouver island. All these tribes are divided into gentes; but, while among the northern tribes, the child belongs to the gens of the mother, among the southern ones it belongs to that of the father. The arts, industries, folk-lore, and other ethnological phenomena of these groups are also different, and the groups have evidently influenced one another.

I shall first show some of these differences by considering the folk-lore of a few of these tribes.

The principal legend of the Tlingit is the well-known raven myth. It is not necessary to dwell upon this myth, as it is known by the reports of many travelers. Vemianow, who lived for a long time among the Tlingit, considers the raven as their supreme deity. It appears from the myths which I collected that besides the raven the eagle is of great importance. One of the legends tells how the raven obtained the fresh water from a mighty chief called Kanuk. This Kanuk is identical with the eagle. Traces of the raven legend are found among all tribes as far south as Komoks. The Kwakiutl consider the raven the creator of the sun, moon, and stars.

The raven legend is not found among the Salish tribes; their supreme deity is the sun, who is called by the Skqómic the great wandering chief, and a great number of myths refer to him. Among the northern tribes of this group and among the Kwakiutl the identity of the sun and the deity is not

so clear; they call the latter Kants'oump (that is, "our father"), or Ata ("the one above"), or Kíkamē ("the chief"). His son, Kanikila, descended from heaven to the earth, and was born again of a woman. When he was grown up, he traveled all over the world, transforming men into animals, and making friends with many chiefs. The same legend is known to the Salish and the West Vancouver tribes. The Komoks call the deity Kumsnootl (that is, "our elder brother"); the Kauitcin, Qäls; the West Vancouver tribes, Alis. He is their culture-hero. In the southern part of Vancouver island it is said that he gave men the fire. The Kwakiutl say that he created the salmon, and gave the law of the winter dance.

These two traditions—the raven legend and the legend of the sun and the son of the deity—are mixed in numerous tribes, particularly among the Kwakiutl. The Bilqula, on the other hand, have both these legends, but a third one in addition. They say that four men—Yulátimot, Masmasalániq, Matlapálitsek, Matlapéeqoek—descended from heaven after the raven had liberated the sun. Then the tradition goes on: And Yulátimot thought, "Oh, might Masmasalániq carve men out of cedar!" and Masmasalániq carved men; and Yulátimot thought, "Oh, might Masmasalániq make a canoe!" and Masmasalániq made a canoe, etc. Yulátimot gives Masmasalániq his thoughts, and Masmasalániq accomplishes them. Thus these two spirits created men and gave them their arts. It is remarkable, however, that by some individuals Yulátimot is described as the raven himself, and he is represented in this way in masks, paintings, and carvings.

From these few remarks it will appear that the mythology of each tribe can only be understood by studying it in connection with that of his neighbors.

Certain mythological ideas, however, are common to all tribes of the north-west coast. The myth of the creation of the world is very uniform among all tribes. The northern group say that in the beginning it was dark until the Raven liberated the sun. The southern tribes say that there was a sun from the beginning, but that daylight was kept in a box by the chief of the sun, and that it was liberated by the Raven. After it had become light, the earth, trees, fire, and water were made. It is remarkable that all these were obtained from some chief who retained them for his own use. Nothing was created. Thus the earth was prepared for man, who descended in the shape of birds from heaven. When they arrived on the earth, the birds threw off their skins and became men. These became the ancestors of the gentes, and each of them received a certain tract of land when the great transformer, Kanikila, met him. Subdivisions of the gentes derive their origin from one of the descendants of these first men. It is told, that in olden times certain men descended into the sea, or went up the mountains, where they met with some kind of spirit, who gave them his emblems. Thus they became the ancestors of subgentes.

Before Kanikila's arrival, animals had the shape of men; but even after they were transformed they were able to appear in the shape of men by taking off their blankets. The northern tribes who do not know the great transformer, say that men were transformed into animals at the time of the great flood.

All tribes consider the sky a solid vault, which can be reached in the far west. After having crawled through a hole in the sky, another land is found, with forests, mountains, ponds, and lakes, in which the Sun and many other spirits live. There is another very remarkable way of reaching this land. The man who intends to go there takes his bow and shoots one arrow into the sky; then he shoots another one, which sticks in the lower end of the first one; and so he goes on shooting until a chain is formed reaching from heaven to earth. I believe that this tradition belonged originally to the tribes of the Salish stock. The Okanagan myth told by Gatschet in Globus, 1887, Vol. 52, No. 9, belongs to this group of legends. It is told in a great number of modifications among the tribes of Vancouver island and the neighboring coast. One of the most important of these is: How the Mink, the son of the Sun, visited his father. This tradition is told by the Kwakiutl and Bilqula. Mink made a chain of arrows reaching to the sky, and climbed up. When he arrived in heaven he found his father, an old man, sitting near the fire. The father was glad to see him, and asked him to carry the sun in his stead. Mink complied with this request, and next morning his father gave him his nose ornament, the sun, and said to him, "Do not go too fast, and don't stoop down, else you will burn the earth." Mink promised to obey, and ascended slowly his path; but when it was near noon, clouds obstructed his way. He got impatient, and wanted to see what was going on, on the earth. He began to jump and to run and stoop down; then the earth began to burn, the rocks to crack, and the ocean to boil. When Mink's father saw that his son disobeyed his orders, he pursued him, tore him to pieces, and cast him into the ocean. There he was found by two women.

Another interesting tradition is told by the Komoks, which in some respects resembles a well-known myth of the Tlingit. In olden times the gum was a blind man. He used to go out fishing during the night, and early in the morning his wife called him back. One day, however, she slept too long, and when she came down to the shore the sun was high up in the sky. She called her husband, but before he could return he had melted. His sons wanted to revenge his death, and made a chain of arrows reaching from heaven to earth. They climbed up and killed the Sun with their arrows. Then the elder brother asked the younger one, "What do you intend to do?" He said, "I will become the moon;" the elder one said, "And I will become the sun."

Another remarkable tradition is told by the same tribe. The son of the Sun ascended a chain of arrows into heaven, and married Tlaiq's daughter. Tlaiq tried to kill his son-in-law, but did not succeed in his attempts. The latter, in revenge, killed Tlaiq. I consider the last-mentioned tradi-

tions of great importance, as both evidently refer to the killing of the old sun and the origin of the new one.

Visits to the Sun, or to the deity which lives in heaven, are frequent in the folk-lore of all these tribes. The Kwakiutl, for instance, tell of a chief's son who ascended to heaven and married the deity's daughter. Their son was the Raven.

The fact that the same mythical beings are known to a great number of tribes shows that the folk-lore and myths of the tribes of the north-west coast have spread from one tribe to another. The raven legend seems to have belonged to the Tlingit and their neighbors, but traces of it are found far south. On the other hand, the sun legend seems to have originated with tribes of Salish lineage; but parts of this tradition are at the present time told by their northern neighbors, and faint traces are even found among the Tsimpshian and the Tlingit.

A number of spirits occur in the folk-lore of most of the tribes of North-west America. One of these is the Tsonokoa, who is evidently a mythical form of the grizzly bear. She is a woman living on high mountains, or, in some instances, in heaven. She visits the villages in order to steal fish, which she puts into a basket that she carries on her back. One tradition says that a man wounded and pursued her. At last he arrived at her house in heaven. He was called in in order to cure her, and did so by extricating the arrows, which none of her companions were able to see. In reward she gave him her daughter, the water of life, and the fire of death, and on his return he became a mighty chief. Another spirit, which is known from Komoks to Bilqula, is Komokoa, a water-spirit, the father of the seals. Many legends tell of men who visited him, or of his visits to villages where he married a woman and became the ancestor of certain gentes. The Sisiutl, a double-headed snake, is known to all tribes from Puget Sound and Cape Flattery to the northern tribes of the Kwakiutl. It is the emblem of many gentes, and its most remarkable quality is that it can assume the shape of any fish or snake.

I have to say a few words about the dances, particularly the cannibal dances, of these tribes. The legend ascribes the origin of the latter to a spirit, Baqbakualanusiuaē. This being lived in the forest. Once a man came to visit him, and when the spirit was about to devour him, he made his escape, Baqbakualanusiuaē pursuing him. When the spirit had almost reached him, he threw a stone behind him, which was transformed into a large mountain. The pursuer had to go all around it, but again he approached. Then he poured out a little fish-oil which he chanced to carry. It was transformed into a lake. Again the spirit approached, and now he threw down his comb, which was transformed into a forest of young trees. He reached his house, and locked the door. When the spirit arrived, he gave him a vessel filled with dog's blood, and said, "Come in. This is my son's blood. You may eat him." But when the spirit accepted the invitation, he threw him into a pit, which he filled with fire, and thus killed him. His ashes were transformed into mosquitoes.

Besides this spirit, the crane, and the so-called "Hámaa," can become the genii of the cannibals. The right to become cannibal is hereditary in certain gentes, but every individual has to acquire it by being initiated. For this purpose he goes into the woods, where he lives for three or four months. After this time, he approaches the village, whistling and singing; then the people know that he has become a cannibal (Hámats'a). The next morning they go into the woods in order to fetch him back. They sit down in a square and sing four new songs which are composed for the occasion. The first song has a slow movement, the second is in a five-part measure, while the third and fourth have a quick movement. As soon as these are sung, the new Hámats'a makes his appearance. He is surrounded by ten men, who carry rattles, and is accompanied by them to the village. All those partaking in the ceremony wear head-rings and neck-rings made of hemlock branches. Four nights the new Hámats'a dances in the house of his father. On the fourth night he suddenly leaves the house, and after a short time returns, carrying a corpse. As soon as the old cannibals see this, they rush forward and cut the corpse to pieces, which they devour. This custom is principally practiced among all tribes of Kwakiutl lineage; but it is also found among the Bilqula and Komoks, who have evidently adopted it from the Kwakiutl. Similar customs prevail among the Tsimpshian. G. M. Dawson says that they have four different systems of rites of religious character, which he calls Simhalait, Mihla, Noohlem, and Hoppop. The third of these are dog-eaters, while the last are the cannibals.

According to my inquiries, this refers to the following tradition: A man went out hunting. After some time he saw a white bear, and pursued it until it disappeared in a mountain. The hunter followed him, and saw that it was transformed into a man, who led him through his house, which stood in the interior of the mountain. There he saw four groups of men, and what they were doing. The first were the Mêítla, the second were the Nootlam ("dog-eaters"), the third were the Wihalait ("the cannibals"), and the fourth were the Semhalaidet. Four days the man staid in the house. Then he returned; but when he came to his village, he found that he had staid in the mountain four years. The bear had told him to do as he had seen the men in the mountain doing. Since that time the Tsimpshian eat dogs and bite men. There are no reports that cannibal ceremonies exist among the Haida and Tlingit.

The masks which all these tribes use in their dances represent spirits or some of the heroes of their legends. Most of the winter dances are pantomimical performances of their traditions. At the great feasts other masks are used, which refer to the tradition of the gens of the man who gives the feast. The use of masks is most extensive among the northern tribes. The variety of masks of the Haida, Tlingit, Tsimpshian, and Kwakiutl, is wonderful, but the more southern tribes have only a very limited number. Among the Nanaimo their use is the privilege of certain gentes. The Lkungen of Victoria use only very few masks, which they destroy by fire as soon as a death occurs in their tribe.

Besides the dances and the use of masks, other customs are common to all tribes of the north-west coast. One of the principal of these is the use of copper-plates. These have frequently been described as being used instead of money, but this is not the case. They are manufactured from copper found on the upper Yukon, and given as presents by one tribe to another. The Indians value a copper-plate the more, the more frequently it has been given as a present. Every single plate has its name and its own house, and is fed regularly. No woman is allowed to enter its house. Almost every tribe has a tradition referring to their origin. Some say that a man who visited the moon received it from the man in the moon. Others say that a chief living far into the ocean gave it to a man who came to visit him, etc. Similar legends refer to the Haliotis shells which are used for ear and nose ornaments and bracelets.

The so-called Potlatch is a feast celebrated by all these tribes. A chief invites all his neighbors, sometimes to the number of a thousand and more, to his house, and presents every one with blankets, skins, and nowadays even with money. The Salish tribes have a kind of scaffold in front of their house, which is used at these festivals. The chief and two of his slaves are standing on it, and distributing the blankets among the guests. Small festivals of this kind are celebrated very frequently. An Indian who has been unsuccessful in hunting, and feels ashamed on this account or for any other reason, gives such a festival to restore his honor.

In the beginning of these feasts four songs are sung, and four different kinds of dishes are served. Then one of the guests stands up and praises the liberality of the host, who, in his turn, replies, praising the deeds of his ancestors. In this speech he frequently uses a mask representing one of his ancestors.

I mentioned above that the social institutions of the northern group and those of their southern neighbors are different; therefore their mortuary customs and marriage ceremonies are also different. The northern tribes burn the corpses of all men except medicine-men. These are buried near the shore, and the corpse of the son is always deposited on top of the corpse of his father. It seems that some of the Kwakiutl tribes used to burn their dead; but by far the greater number of tribes of this stock either hung up the dead in boxes in top of trees, the lower branches of which were removed, or deposited these boxes in burial-grounds set apart for this purpose. Chiefs are buried in a separate place. Food of all kinds is burned for the dead on the shore.

I shall describe their mourning ceremonies as illustrative of those in use of most of the coast tribes. The mourning lasts for a whole year. For four days the mourner is not allowed to move. On the last of these days all the inhabitants of the village have to take a bath. On the same day some water is warmed and dripped on the head of the mourner. For the next twelve days he is allowed to move a little, but he must not walk. Nobody is allowed to speak to him, and they believe that whosoever disobeys this command will be punished by the death of one of his relatives.

He is fed twice a day by an old woman, at low water, with salmon caught in the preceding year. At the end of the first month he deposits his clothing in the woods, and then he is allowed to sit in a corner of the house, but must not speak to the other people. A separate door is cut, as he is not allowed to use the house door. Before he leaves the house for the first time, he must approach the door three times and return without going out. Then he is allowed to leave the house. After four months he may speak to other people. After ten months his hair is cut short, and the end of the year is the end of the mourning period. After the death of a chief, his son gives a great festival, in which he takes the office and name of his father. At first, four mourning songs are sung, which have a slow movement, and then the son of the chief stands up, holding the copper-plate in his hand and saying, "Don't mourn any more. I will be chief. I take the name of my father."

The marriage ceremonies of the Kwakiutl tribes are very remarkable. The dowry of the bride consists of bracelets made of beaver toes, copper-plates, so-called "button-blankets," and the Gyíserstal. The latter is a board, the front of which is set with sea-otter teeth. It is intended to represent the human lower jaw; and the meaning is, that the bride will have to speak or be silent, as her husband may desire. Before and after the marriage, the son-in-law gives many presents to his wife's father. If the woman intends to return to her parents, her father must repay all he has received from his son-in-law. This is done frequently, in order to give an opportunity to the father-in-law to show his liberality and wealth. As soon as he has paid the husband, the latter repurchases his wife. The use of the Gyíserstal is very limited. I found it only among the Kwakiutl proper and Nimkish.

I do not intend to describe the houses, the hunting and fishing, and industries of all these tribes, neither will I attempt to discuss the character of the art products of the different groups. I have endeavored to show in my remarks that the culture of the Northwest American tribes, which to the superficial observer seems so uniform, originates from many different sources, and that only a thorough knowledge of the languages, folk-lore, and customs of these tribes and their neighbors will enable us to trace at least part of their obscure history.

Electrolysis of Lead Solutions. Determination of Boric Acid. Dihalogen Derivatives of Salicylic Acid. Barite. By Edgar F. Smith.

(*Read before the American Philosophical Society, Nov. 18th, 1887.*)

The following is a report of work prosecuted in the laboratory of Wittenberg College, Springfield, Ohio, during the past year, partly by myself and partly by students under my supervision:

I. Electrolysis of Lead Solutions.

Lead is one of the metals which has given analysts considerable trouble

to estimate electrolytically; consequently, many suggestions have been offered, as to the best course to pursue in determining it in this manner. In this note I purpose giving some results obtained by using an alkaline solution of lead containing a phosphate. Employing a lead solution with an unknown quantity of lead, I took from it, 5 c.c., to which I added an excess of disodium phosphate, dissolving the precipitate formed in sodium hydroxide, then subjected the liquid to the action of a current derived from three small Grove cells, for a period of two hours, after which the action was interrupted; the deposit of metallic lead was washed with water, alcohol and ether, then carefully dried and weighed. In this manner I obtained .0105 grs. Pb. A second experiment conducted under like conditions gave a similar result. With 10 c.c. of the lead solution the following amounts of lead were obtained:

1. .0210 grams Pb.	3. .0213 grams Pb.
2. .0215 " "	4. .0210 " "

The same current strength was used in all these determinations, but the time varied from two to four hours. In all instances, the precipitated metal showed a regular, compact appearance.

I analyzed another lead solution of unknown strength, using, as before, sodium phosphate and hydroxide, and obtained:

$$\left.\begin{matrix} .0235 \text{ grams} \\ .0217 \quad " \end{matrix}\right\} \text{ Pb.}$$

The current was from three small Grove cells. Time, 3½ hours.

Subsequently, I dissolved 8.7315 grams of lead nitrate in 250 c.c. water, and treated as follows:

1. One c.c. of the solution was precipitated by sodium phosphate, the precipitate dissolved in sodium hydroxide and the solution exposed to the action of a current from two Grove cells for two hours. In this way I obtained a lead deposit equal to .0215 grams Pb. The metal, after being washed with water, was dried in a current of hydrogen. This seemed necessary and was done in the following determinations:

2. Same as in 1; obtained .0220 grams Pb.

3. Same as in 1; obtained .0213 grams Pb.

4. Same as in 1; obtained .0220 grams Pb.

The theoretical amount of lead in the electrolyzed solution was .0219 grams.

These experiments indicate that the metal can be deposited in good form from an alkaline phosphate solution, but to insure satisfactory results, great care must be exercised in the drying, as the moist metal oxidizes readily.

II. Experiments in the Determination of Boric Acid. By E. B. Knerr.

It was observed that a considerable quantity of uranium nitrate could be added to a borax solution containing potassium ferrocyanide before the

characteristic red-brown precipitate of uranium ferrocyanide appeared. This suggested the possibility of obtaining a quantitative method for the estimation of boric acid. I, therefore, dissolved 4.18 grams of uranium nitrate in one litre of water, and 1.16 grs. of well-crystallized borax in 250 c.c. water. The uranium solution was then placed in a burette and carefully added to definite portions of the borax solution until a drop of the mixture, added by means of a thin glass rod, to a drop of a concentrated potassium ferrocyanide solution, on a porcelain plate, gave a reddish-brown color. The first distinct coloration was regarded as the final reaction. The following results were obtained:

1.	5 c.c.	of the	borax	solution	required	8.8 c.c.	uranium nitrate.
2.	"	"	"	"		8.9 "	"
3.	"	"	"	"		8.8 "	"
4.	"	"	"	"		8.8 "	"
5.	"	"	"	"		8.8 "	"
6.	"	"	"	"		8.8 "	"
7.	"	"	"	"		8.8 "	"
8.	"	"	"	"		8.8 "	"
9.	"	"	"	"		8.8 "	"
10.	10 c.c.	"	"	"		17.7 "	"
11.	"	"	"	"		17.6 "	"

A second uranium nitrate solution, containing 8.6267 grams nitrate in 500 c.c. of water, was standardized as above with a borax solution (containing .9051 grams borax in 250 c.c. water). The results were as follows:

1.	5 c.c.	borax	solution	required	1.35	c.c.	uranium nitrate.
2.	"	"	"	"	"	"	"
3.	"	"	"	"	"	"	"
4.	"	"	"	"	"	"	"
5.	"	"	"	"	"	"	"

From this we discover that 1 c.c. of uranium solution equaled .004917 grams B_2O_3.

To test the accuracy of the method, I dissolved 1.1762 grams freshly crystallized borax in 250 c.c. of water, and titrated portions of it with the above standardized uranium solution:

1.	10 c.c.	of borax	solution	required	4.0 c.c.	uranium solution.
2.	"	"	"		3.5 "	"
3.	"	"	"		3.4 "	"
4.	"	"	"		3.5 "	"
5.	"	"	"		" "	"
6.	"	"	"		" "	"
7.	"	"	"		" "	"

Taking 10 c.c. of the borax solution as equivalent to 3.5 c.c. of the uranium solution, we have the 250 c.c. of the borax solution equal to 85 c.c. of the uranium solution ; but the 85 c.c. represent 85 × .004917 grms. B_2O_3 = .43023 grms. B_2O_3 or 36.57%. The theoretical amount of boric acid in 1.1767 grms. borax is .43114 grs. B_2O_3 or 36.64%.

Free acid very materially affects the results. Extremes of dilution also influenced the same to a certain degree.

I next endeavored to ascertain how ferric salts would act upon borax. At first, potassium ferrocyanide was employed as an indicator, but was later rejected. On substituting potassium sulphocyanide for it, a few drops of the same were placed in the vessel containing the borax. The first decided "blush" which came over the solution was counted as the end of the reaction. I standardized a definite amount of ferric ammonium sulphate with a definite quantity of borax, finding that one c.c. of the iron solution was equivalent to .004479 grams B_2O_3. I then dissolved 1.2651 grms. of borax in 250 c.c. of water, and titrated a number of portions with the standardized iron solution. The results were 36.73% B_2O_3, instead of 36.64% by theory.

Upon standardizing a new quantity of iron salt, instead of adding the sulphocyanide solution directly to the borax solution, a few drops of it were placed upon a porcelain plate, and as the end reaction was approached, portions of the liquid were brought in contact with the sulphocyanide by means of a glass rod. In this way the following numbers were obtained :

1.	10	c.c.	borax solution	required	1.05	c.c.	iron solution.
2.	"	"	"	"	"	"	"
3.	5	c.c.	"	"	0.5	"	"
4.	10	"	"	"	"	"	"
5.	5	"	"	"	0.5	"	"
6.	10	"	"	"	1.05	"	"
7.	"	"	"	"	"	"	"
8.	20	"	"	"	2.10	"	"
9.	"	"	"	"	"	"	"
10.	40	"	"	"	4.20	"	"

Thus, I found that one c.c. of the iron solution was equal to .00967 grms. B_2O_3.

The following tests were then made with the iron solution :

1. 2.2741 grms. borax were dissolved in 250 c.c. of water, and portions of it titrated :

10	c.c.	borax	required	3.40	c.c. iron solution.
"	"	"	"	"	"
"	"	"	"	"	"
20	"	"	"	"	"

This gave 36.14% B_2O_3 ; theory 36.64%.

2. Six determinations were made with a solution containing 2.1490 grms. borax in 250 c.c. water.

   Found 36.40% B_2O_3, instead of 36.64%.

3. With a solution containing .0865 grms. of borax, I obtained 36.89% B_2O_3.
4. .0254 grms. borax, dissolved in water and titrated, showed 36.46% B_2O_3, instead of 36.64%.
5. .0104 grms. borax gave 37.50% B_2O_3.
6. .0198 grms. borax, titrated as before, gave 36.35% B_2O_3.

A number of determinations showed that sodium salicylate can also be advantageously employed as an indicator.

For rapid work, where approximate results are sufficient, the foregoing methods will no doubt be of service. Free acids should always be avoided.

I have also experimented with tungstic and molybdic acids in the same manner, and while the results are very promising, I prefer reserving an account of the same until the details have been fully worked out.

III. Dihalogen Derivatives of Salicylic Acid. By W. S. Hoskinson.

In the *American Chemical Journal*, Vol. viii, No. 2, Smith and Knerr described metachloriodosalicylic acid and its derivatives. Pursuing a somewhat similar line of research, I prepared a brom-chlor-acid, and an iodo-brom-salicylic acid, as well as derivatives of the same. Below I give a brief description of these new compounds.

Brom-chlor-salicylic Acid.

C_6H_2 OH BrCl COOH.

To obtain this acid I used a definite quantity of metachlorsalicylic acid (m.p. 172° C.), and dissolved the same in alcohol. To this solution was gradually added a corresponding, equivalent amount of bromine; the flask in which the reaction was performed was kept cool. When the entire quantity of bromine was added, the alcoholic solution was evaporated to dryness upon a water-bath. The residue was boiled with water and barium carbonate, the liquid filtered and allowed to cool. The barium salt separated in bushy needles. Its solubility in water is about 1 : 100. The sodium salt was prepared from the barium salt, and from it the acid was liberated by hydrochloric acid. The free acid forms small, white needles, nearly insoluble in boiling water, but soluble in alcohol. In its pure state it melts constantly at 229° C.

The *barium salt* [$(C_6H_2$ OH BrCl $CO)_2$ Ba + $4H_2O$] forms long bushy needles, soluble with difficulty in boiling water. An analysis of it gave 10.02% H_2O and 21.20% Ba. The formula given requires 10.14% H_2O and 21.48% Ba.

The *sodium salt* (C_6H_2 OH BrCl COONa + $1\frac{1}{2}$ H_2O) appears in beautiful bunches of white needles, which are very soluble in water. An

analysis showed 9.09% H_2O and 8.25% Na; theory requires 9.89% H_2O and 8.40% Na.

The *calcium salt* is anhydrous. Its analysis gave 7.42% Ca, while theory requires 7.39%.

The *zinc salt* forms small crystals, much like fish-eggs. It dissolves with difficulty in hot water. When analyzed it gave 13.91% H_2O and 12.24% Zn; the theoretical figures are 14.06% H_2O (5 molecules), and 11.94% Zn.

The *magnesium salt* does not crystallize well. It is not readily soluble, even in hot water. It contains six molecules of water of crystallization. Upon analysis I obtained 17.19% H_2O and 5.33% Mg. The calculated percentages of water and magnesium are 17.03% and 4.79%.

The *cadmium salt* forms beautiful crystals.

The *silver salt* was obtained as a white precipitate insoluble in water. I employed it in preparing the methyl and ethyl esters.

Methyl Ester (C_6H_2 OH BrCl CO OCH_3). This was obtained by the action of methyl iodide upon the silver brom-chlor-salicylate. It forms beautiful needles, dissolving with difficulty in both alcohol and ether. It melts at 126–127° C. This ester was burned with lead chromate, and gave good results. The *ethyl ester*, also prepared, was not further studied.

The free brom-chlor acid was burned with lead chromate. The result showed 33.07% carbon and .96% H. Theory requires 33.46% C and 1.53% H.

Iodo-brom-salicylic Acid.

C_6H_2 OH IBr COOH.

Metabrom-salicylic acid was first prepared, and then iodated by the method of Weselsky. Little heat was evolved in the reaction; sometimes this was added by means of the water-bath. When the reaction was complete the alcoholic solution was removed to an evaporating dish and run down to dryness. The residue was boiled with water and barium carbonate; from the hot filtrate the barium salt crystallized out, but it was immediately converted into the sodium salt, from which I set the acid free. The latter forms small, beautiful needles, dissolving with difficulty in hot alcoholic water. It melts at 208–209° C. A combustion of the pure acid gave 24.17% carbon and 1.30% H, instead of 24.48% C and 1.17% H.

The *barium salt* contains three molecules of water. It forms branched, purple-tinted needles. An analysis gave 6.48% H_2O and 15.55% Ba, instead of 6.27% H_2O and 15.65% Ba, as required by theory.

The *sodium salt* contains one molecule of water. It forms nodules, consisting of silky needles, very soluble in water. When analyzed it yielded 5.20% H_2O and 6.08% Na; theory requires 4.70% H_2O and 6.30% Na.

The *calcium salt* resembles the barium salt in form; it is possibly somewhat more soluble in hot water. It contains four molecules of water. Its

analysis gave 8.04% H_2O and 5.65% Ca, instead of the theoretical 8.01% H_2O and 5.53% Ca.

The *cadmium salt* forms beautiful needles, readily soluble in water. Its analysis showed 8.21% H_2O and 14.13% Cd, instead of 8.29% H_2O and 14.19% Cd.

The *zinc salt* consists of indistinct needles, readily soluble in water. Its analysis showed the presence of five molecules of water, and 10.51% Zn.

The *methyl ester* crystallizes in beautiful needles, which melt at 104–105° C. By its combustion I obtained 26.23% C and 2.15% H. Its formula requires 26.86% C and 1.68% H.

The study of other mixed dihalogen derivatives of salicylic acid is being carried forward in this laboratory, the results of which will be published later.

IV. Barite from Ludlow Falls, Miami County, Ohio.
By Charles H. Ehrenfeld.

This mineral was found in the summer of 1886, the chief interest in connection with it being that it is the first time barite has been found in this locality. It is white, semi-transparent and massive, and it occurs in the Niagara limestone, associated with small crystals of pyrite, the surface of which is brown owing to oxidation. The average of four sp. gr. determinations of the barite is 4.48.

An analysis showed the following composition:

$BaSO_4$	91.10%
$SrSO_4$	7.63 "
$CaSO_4$	.98 "
Total	99.71%

CHEMICAL LABORATORY OF WITTENBERG COLLEGE,
Springfield, Ohio, Nov. 8, 1887.

Stated Meeting, December 2, 1887.

Present, 34 members.

President, Mr. FRALEY, in the Chair.

Dr. Morton W. Easton was presented to the Chair and took his seat.

Correspondence was submitted as follows: Letters acknowledging receipt of diploma from Messrs. R. N. Toppan, Cambridge, Mass.; William John Potts, Camden, New Jersey; Charles A. Oliver and Henry Reed, Philadelphia.

A letter of envoy from Das K. Württ. Statistische Landesamt (Stuttgart).

Letters acknowledging the receipt of the Proceedings, No. 125, from: Bibliothéque Impériale Publique, Library of the Academy of Sciences, Comité Geologique de la Russie, Observatoire Physique Central, Prof. Serge Nikitin, St. Petersburg; K. Bibliothek, K. Geologische Landesanstalt and Bergakademie, Berlin; Verein für Thüringische Geschichte und Alterthumskunde, Jena; Publishers of "Natur-Forscher," Tübingen, Würtemberg; Prof. Remi Siméon, Paris; Amer. Statistical Association, Boston; Akademie der Wissenschaften, Wien; Dr. Hugo von Meltzel, Hungary; Messrs. Friedländer & Sons, Berlin; K. Sächsischer Alterthums Verein, Dresden; Verein für Thüringische Geschichte und Alterthumskunde, Jena; Deutsche Gesell. für Anthrop., etc., München; K. Würtembergisches Statistisches Landesamt, Stuttgart; Nassauischer Verein für Naturkunde, Wiesbaden; Institut R. Grand Ducal de Luxembourg; Soc. R. Malacologique de Belgique, Acad. R. des Sciences, etc., Bruxelles; Instituto y Observatoire de Marina de San Fernando, Madrid; Publishers of "Nature," London; Museum of Comparative Zoölogy, Cambridge, Mass.; Vassar Brothers' Institute, Poughkeepsie; Messrs. Wm. M. Meigs, Henry Phillips, Jr., Richard Vaux, Philada.; Johns Hopkins University, Baltimore; U. S. Commissioner of Fish and Fisheries, Bureau of Navigation, U. S. Department of Agriculture, Washington; University of California.

A letter was read from Professor Rothrock, enclosing tickets for his Free Michaux Forestry lectures under the auspices of the American Philosophical Society and the Pennsylvania Forestry Association, at the University of Pennsylvania.

Circulars were read as follows: From Prof. Antonio Favardi, of Milan, Italy, announcing the preparation of a new edition of the works of Galileo. From the "Record Society," Pensarn, Abergele, North Wales, in reference to its publication of original documents relating to Lancashire and Cheshire. From the publishers of "The American Geologist," announcing the issue of a new journal under that title.

Prof. Daniel Kirkwood (Bloomington, Indiana) presented, through the Secretaries, a communication, entitled, "Note on the possible existence of Fireballs and Meteorites in the Stream of Bielids."

The Report of the Committee on *Volapük* was read, after which a discussion upon the subject-matter of the Report ensued, participated in by the members, and ultimately, on motion of Mr. McKean, the whole subject was recommitted.

The Report of the Treasurer was presented and referred to the Finance Committee, and the Society was adjourned by the President.

Note on the Possible Existence of Fireballs and Meteorites in the Stream of Bielids. By Daniel Kirkwood.

(*Read before the American Philosophical Society, December 2d, 1887.*)

A revision of my paper on this subject, read September 2d, 1887, suggests the following modifications:

1. Before 1832, the earth passed the comet's node early in December. The first eight meteors of the list should therefore be rejected.

2. In Greg's Catalogue the circumstances which indicate the radiant are not generally given; the probability that the meteors belong in part to the stream of Bielids must be judged by a comparison of their relative numbers with the mean number during a specified time. In the thirty years from 1831 to 1860, the list gives seven hundred and twenty-one fireballs and meteorites, or six for any three days of the year taken at random. The number for November 28–30 is twelve, or twice the average. Of these, one is the meteorite which fell during the shower of Bielids on November 27th, 1885; one is the conformable fireball of November 28th, 1850, the date of a well-marked shower of shooting stars; three (1839, 1848, and 1850, Nov. 30) are non-conformable; and the directions of the remaining seven are unknown, at least to the writer. Mr. Greg calls attention to November 27–30 as an aerolitic epoch coincident with one of shooting stars.

3. The attempt in my paper of September 2d, to trace a period approximately equal to that of Biela's comet was probably premature.

Ancient Human Footprint on Tufa, from Nicaragua.

On an Ancient Human Footprint from Nicaragua.

By D. G. Brinton, M.D.

(*Read before the American Philosophical Society, Nov. 18th*, 1887.)

The discovery of human footprints in volcanic rocks near the shore of Lake Managua, Nicaragua, under circumstances which seemed to assign them a remote antiquity, has been announced for several years.* We owe thanks especially to Dr. Earl Flint, of Rivas, Nicaragua, for information about this discovery, and for sending several specimens to the United States. Four of these are in the Peabody Museum of Archæology, Cambridge, and recently, I have myself received one from Dr. Flint, together with several letters describing the locality. The possession of this material has induced me to present, along with its description, a general review of the subject.

The surface of the Republic of Nicaragua presents in nearly all parts the signs of enormous volcanic activity. It is broken by a complex series of mountain ranges whose sides are scored with vast lava streams. Frequent earthquakes attest the continued energy of the subterranean forces and prepare us for incidents of elevation and subsidence on an uncommon scale.

The great lakes of Nicaragua and Managua are divided by a low plain through which flows the river Tipitapa connecting these sheets of water. South of this lowland rises a mesa or tableland 400 or 500 feet above the level of the lakes, and upon this stand the volcanic cones of Mombacho (4588 feet) and Masaya (2972 feet). Beyond these, the land still rising, reaches its height in the Sierras de Managua, presenting the craters of the extinct volcanoes of Tizcapa, Nezcapa (Nehapa), and Asososco; and further to the north-west, immediately upon the shores of the Lake Managua, the still smoking peaks of Chiltepec (2800 feet) and Momotombo (6121 feet).

The last named (Momotombo) was active in 1852, and Masaya in 1858 and 1872, while Mombacho, though quiet, so far as we know, since the conquest, according to tradition, destroyed an important town just before that epoch, and its sides still reveal signs

* The following are the principal references: Letter of Dr. Flint, dated Jan. 7, 1884, in the *American Antiquarian*, March, 1884; *17th Report of the Peabody Museum* for 1884, page 356; *18th Report* of the same, 1885, page 414; *Proceedings of the American Antiquarian Society*, 1884, p. 92. Letter of Dr. Flint in *American Antiquarian*, May, 1885.

of terrific outbursts at no distant date. In the eruption of March, 1872, Masaya vomited a lava stream two miles in width.*

I quote these facts to show the volcanic character of the country and the powerful agencies at work there.

For our present purpose, we have to confine our attention to the extinct volcano of Tizcapa. Like its neighbors, the cones of Nezcapa and Asososco, it has long since burnt out its fires, and all three have changed their flaming craters into deep and still lakes, encircled by precipitous walls of congealed masses. Tizcapa is about two and a-half miles from the shore of Lake Managua, and in ancient times its molten streams found their way into the waters of the lake. Its eruptions were irregular, and evidently long periods of quiescence intervened between those of violent action, periods extended enough to allow the earlier tufa beds and lava streams to become covered with vegetation, the relics of which we find imbedded beneath later overflows. How much time this would require is a vital question in deciding the age of the footprints. These are found on the surface of the *first* or lowest tufa bed, which itself rests upon a bed of yellow sand.

Before proceeding to a discussion of the antiquity we may fairly assign to the relic, I shall insert Dr. Flint's description of the locality, and add a vertical section of the cutting in the quarry on the lake shore, in which the footprints are found. Both of these he has kindly sent me in a recent letter.

"The Cordilleras east of Lake Nicaragua are a continuous succession of low mountains, spread out and gradually diminishing to the depression, where the outlet of Lake Nicaragua passes seaward by the San Juan river. In past ages the spur west of the lakes Nicaragua and Managua (formerly part of an ocean inlet) was the theatre of volcanic action seldom exceeded; and its latent fires, out of the axial line, at Ometepetec and Momotombo, still smoke. These magnificent cones may continue to burn for ages, until they disappear, like their neighbors, leaving like them, an abyss to mark their location.

"Zapatero has its deep lake, whose surface is but slightly above the waters of the one surrounding it; north-west and near Granada, we look down from the edge of the old crater on a

* See Pablo Levy, *Notas sobre la Republica de Nicaragua*, pp. 83, 84 (Paris, 1873), and A. Schiffman, *Una Idea sobre la Geolojia de Nicaragua*, p. 125 (Managua, 1873).

placid lake, whose four square miles of water are seldom stirred by the wind, and whose depth has not yet been fathomed. When were the fires of this immense crater extinguished?

"Lake Masaya far exceeds that of Apoyo; as we descend the deep ravines cut through the tufas to its margin, we see the work of centuries carrying back this detritus to refill the abyss, and no perceptible diminution is noted. Passing on, we find the lakes Nehapa, Asososco, and Tizcapa, under similar conditions; the latter near Managua, furnished the material forming the tufas on which the footprints occur.

"These lakes at the time of the Spanish occupation, now nearly four centuries, presented nearly the same aspect as they do now; their rock-bound shores were covered with inscriptions, of which no tradition could be obtained of the tribes then occupying this region. The country was clothed with impenetrable forest that had sprung up on these arid wastes of tufa. We dig below this fertile soil, and after removing five well-marked beds of tufa, including a lower one of pure ash, we encounter a deposit of clay, a soil of other times, accumulated under circumstances familiar to that now on the surface. It also had its plants and trees. Among the former we see long liriaceous leaves impressed on the friable deposit. We ask, is this the soil of the first inhabitants? Before deciding, we dig below, through four more deposits, with other accumulations in the seams, of pumice and volcanic sand. We reach a thin friable tufa, nearly black, about two inches thick; removing it, we find a heavy deposit of tufa lying on yellow sand. This is the last in the series; on its upper surface we find innumerable footprints of a people who had passed over it, at different times, when in a plastic state. Some sank deep in the mass, while others left superficial impressions. Now and then, a stray leaf of that horizon was trodden into the imprints; others are on the friable under-surface; they seem to differ from those above under the ash."

Dr. Flint sends me a vertical section of the quarry from which the present specimen was taken. The location is about 300 feet from the shore and close to the town of Managua. At that point the overlying strata present a thickness of twenty-one feet beneath the surface soil, the most of the mass being compact tufa, similar in general appearance to the block bearing the imprint.

Vertical section, 21 feet in depth, of a Quarry on Lake Managua, showing strata overlying human footprints.

1. Surface soil, about 18 inches.
2. Compact tufa, 20 inches, separated from No. 3, by a sand seam.
3. Compact tufa, 20 inches, separated from No. 4 by a sand seam.
4. Compact tufa, 17 inches, separated from No. 5 by a sand seam.
5. Compact building tufa, 28 inches, resting on a seam of black sand.
6. Solid, dark-blue ash, 14 inches.
7. Hard clay, 12 or more inches, its surface presenting numerous leaves (impressions, fossils), and remains of the mastodon.
8. Pumice, about two inches, unequally distributed.
9. Sand drift, supporting the clay.
10. Compact building tufa, 47 inches, separated from No. 11 by a sand seam.
11. Compact tufa, 5 to 7 inches.
12. Black sand, 1 inch.
13. Dark, friable tufa, 2 inches.
14. Volcanic sand, containing fossil leaves, 1 inch.
15. ..... The dotted line ..... shows the horizon of the footprints impressed upon number
16. Compact building tufa, 47 inches.
17. Yellow sand, believed to be Eocene (?) of undetermined thickness, containing numerous small shells.

Beginning with the lowest stratum, the yellow sand, the only clue offered to ascertain its age, believed by Dr. Flint to be Eocene, is the shells which it offers in abundance, but apparently only of one species. They are small and well preserved. Dr. Flint transmitted a number of them for examination to Prof. Newcombe, of Cornell University, who considered them a new species, and has called them provisionally *Pyrula nicaraguensis*, and adds that the genus is represented in North America by but one other species, *P. nevadensis* Stearn.

I submitted a number of them to my colleague at the Academy of Natural Sciences, Prof. Angelo Heilprin, who writes me:— "I should not like to pronounce positively upon the age of the deposit represented by the Nicaraguan shells, as by themselves they scarcely give direct evidence. But I should incline to the opinion that the deposit in question is more nearly Post-pliocene than Eocene, the specimens having a decidedly new look, and lacking the Eocene tertiary characters."

Dr. Flint sent to the Peabody Museum a number of leaves from the deposit marked 14 on the section; and I have recently inquired of the authorities of the Museum whether their age and character have been determined. They reply, that these characters have not yet been made out.

The hard clay deposit, No. 7 of the plan, increases in thickness in other localities to ten or twelve feet. It is considered by Dr. Flint to represent a period of repose of many centuries, and on its surface, bones of the mastodon have been found at other points along the lake. It is the only deposit in the section which seems to demand considerable time; and even here, the question will suggest itself whether a submergence of the lake shore for a few centuries or less might not be sufficient to produce this deposit. The presence of the mastodon bones is no evidence of great antiquity. That huge herbivore lived in tropical America almost in historic times. A complete skeleton of one was found not long since in an *artificial* salt pond, constructed by the Indians, near Concordia, Colombia. The pond, with its bottom of paved stones together with the animal, had been entombed by a sudden landslide.*

* See R. B. White, "Notes on the Aboriginal Races of the Northwestern Provinces of South America," in the *Journal of the Anthropological Institute of Great Britain*, February, 1884, p. 244.

PROC. AMER. PHILOS. SOC. XXIV. 126. 3D. PRINTED DEC. 29, 1887.

The deposit of ashes, No. 6 on the section, is held by Dr. Flint to mark a period of volcanic energy of wide extent and important consequences in modifying the physical geography of the region. It led to the elevation of the coast range and the separation of Lake Nicaragua, previously a bay of the ocean, from the sea. Dr. Flint's expressions are:

"West of Jinotepe a well was sunk one hundred and nineteen varas in search of water; there this ash deposit is fifteen feet thick, at least twenty miles from the nearest crater.

"We see many proofs, that the cataclysm enclosing Lake Nicaragua (formerly salt water) was at the time of this ash eruption; while the tufas, *previously ejected*, pushed over the sea inlet at Tipitapa, enclosing that of Managua; they were not broken up by the cataclysm, nor those at the quarry, and all on the northern slope; nor the slip of coast north and south of San Rafael."

Passing to a study of the tracks themselves, they are described by Dr. Flint as quite numerous and passing in both directions, that is, to and from the lake shore, from which the average distance of those found is about 300 feet. The maximum stride was 18 inches, and the longest foot measured 10 inches.

The specimen which he has sent me, and which is offered for inspection [specimen presented], is the impression of a left foot. The total length of the impression is 9½ inches, the breadth at the heel 3 inches, at the toes 4½ inches. The apparent length of the foot itself was 8 inches. The instep was high, and the great toe large, prominent and exceeding in length the second toe. This last peculiarity has been by some considered of ethnic importance.* The greatest depth of the impression is at the ball of the foot, the weight being evidently thrown forward as in vigorous walking. At this part the maximal depression below the plane of the superfices is 2 inches.

The footprints on the tufas at Managua are not the only ones discovered in that Republic by Dr. Flint. Others were seen on the southern slope of the Sierra de Managua, near the town of

* See J. Park Harrison, "On the Relative Length of the First Three Toes of the Human Foot," in the *Journal of the Anthropological Institute of Great Britain*, February, 1884. The general conclusion seems to be that a long second toe indicates a lower stage of development.

San Rafael. The character of this horizon is thus described by Dr. Flint in a letter to me:

"Collateral evidence touching man's antiquity here, not less weighty, is found in the neighborhood. The eruptions covering the south-west slope, and the disturbance caused by one, along the ocean beach, elevating the coast range, affords us indisputable evidence of Pliocene man. In descending the slope through immense ravines formed by the annual floods, we see enormous blocks of tufa, isolated by the removal of the material surrounding them, showing that they had been uplifted by some mighty force and re-embedded in the resultant débris.

"In 1875–8 and 1883, I spent over a month visiting the coast-hills to the south-west about San Rafael, seeking out the limits of the cataclysm.

"A strip of land, commencing at Bocano, extends along the coast about forty miles and widens out about San Rafael, terminating some eighteen miles above the latter place, at the base of the old primitive range. South-east of the town, a notable break in the upheaval shows that this strip was undisturbed, while the succession of hills to the east and south-east widens out and extends to the south at San Juan del Sur, and thence to Salinas bay. The force culminated against the south-west slope of the old primitive volcanoes mentioned, also shown north-west of San Rafael, where the tufa of the first eruption, on the slip of land mentioned, was unbroken, while in ravines near, the ocean sediment of the upheaval overrides it, forced over it as the rise occurred near by to the east.

"This sediment has been carried seaward by the rivers since formed. As they removed the debritus from the tufa, these were found covered with footprints of animals and man. One of these (sandal shod) was forwarded to the Peabody Museum.

"Where the rivers have cut through the old sea sediment down to the primitive rock, we see beds of shells of many species, among them enormous oysters of an oblong figure, perfect fossils, yet unnamed. They are *in situ*. Their contents resemble slaked lime. All this shows a sudden elevation. A few can be seen at the National Museum with the fossil leaves in the rock above them, similar to those on the Managua clay under the ash eruption. The latter eruption broke up the clay and elevated the

coast range. On the neighboring hills innumerable shells are adherent to the fractured limestone, and south to those west of Rivas; from there the limestone dips to south-east and is only about sixty metres above the sea between San Juan and Virgin bay, while part of the Rivas plateau was undisturbed."

It will be observed that one of these footprints indicates the use of sandals or moccasins by the pedestrians of that day. None of this character have been reported from Managua. Undoubtedly a society which wears shoes cannot be assigned to the earliest stages of human culture. Many of the natives of Central America to this day never protect the feet in any manner.

In conclusion, I should say, that there can be no doubt of these being genuine human footprints. They are not of that mythical origin which the fancy of savage nations delights to imagine,* nor can there be the least doubt of their authenticity. Their antiquity remains uncertain. In regions at once tropical, fertile and volcanic, we may expect sudden upheavals and subsidences, and the ravages of the most violent outbursts are repaired by a luxuriant vegetation with surprising rapidity. My own opinion is, that there is not sufficient evidence to remove them beyond the present Post-pliocene or Quaternary period.

Stated Meeting, December 16, 1887.

Present, 27 members.

President, Mr. FRALEY, in the Chair.

Correspondence was submitted as follows: Letters of envoy were received from Société R. des Sciences à Upsal; Fondation de P. Teyler van der Hulst à Harlem; Società Italiana della Scienze, Torino; Lords Commissioners of the Admiralty, London; U. S. Naval Observatory, U. S. Geological Survey, Washington, D. C.

A letter from Lord Rayleigh, London, acknowledging receipt of his diploma.

A letter was read from Prof. March, Easton, Pa., in refer-

* See Dr. Richard Andree, on "Fussspuren," in his *Ethnographische Parallelen und Vergleiche*, s. 94 (Stuttgart, 1878).

ence to the lately-appointed commission to determine upon a uniform mode of spelling in public documents, etc., of the State of Pennsylvania.

The American Association for the Study of Modern Languages was invited to visit the Society's Hall during its approaching session in this city.

Letters of acknowledgment from Imperial Russian Geographical Society, St. Petersburg (125); Prof. Otto Donner, Helsingfors (125); Société R. des Sciences, Upsal (123, 124 and List of Members); Captain Richard Temple, Mandalay (125).

Letters were read from the Engineers' Club of Philadelphia, inviting the officers of the Society to be present at its Reception, December 17, 1887, the Decennial Anniversary of the Foundation of the Club;

From the Rutland County (Vermont) Historical Society, requesting Constitution, Laws, etc.;

From the Smithsonian Institution, announcing the election of Prof. Samuel P. Langley, LL.D., as Secretary;

From the Oneida County Historical Society, in reference to a celebration of the New Hartford Centennial.

A circular was read announcing the proposed issue of a new journal to be called *The American Anthropologist.*

Accessions to the library from Royal Society of Tasmania; Geological Survey of India, Calcutta; Naturforschender Verein, Riga; K. B. Akademie der Wissenschaften, München; Société R. des Sciences, Upsal; Fondation de P. Teyler van der Hulst, Harlem; Società Italiana della Scienze, Torino; Publishers of "Cosmos," Paris; Lords Commissioners of the Admiralty, London; Philosophical Society, Cambridge; Radcliffe Observatory, Oxford; Philosophical Society, Glasgow; Messrs. Henry W. and Henry V. Poor and Charles E. Sprague, New York; Mr. Henry Phillips, Jr., Philadelphia; Johns Hopkins University, Baltimore; U. S. Geological Survey, U. S. Naval Observatory, Washington, D. C.; Prof. J. W. Mallett, University of Virginia.

The death of Dr. Middleton Goldsmith (Rutland, Vermont), on November 26, 1887, æt. 70, was announced.

This being the evening for the consideration of communications pending for the Magellanic Premium, the Society discussed the claims of one signed "Magellan" on the "Physical Phenomena of Harbor Entrances; Their Causes and Remedies; Defects of Present Methods of Improvement," and on being put to a vote it was unanimously resolved that the Society would consider the claims of the said paper.

Upon the question then recurring as to whether the said communication was worthy of the proposed premium, a vote was taken and the Society unanimously resolved that the said communication was worthy of the premium, and that the Magellanic Premium should be awarded therefor.

The sealed letter accompanying the crowned performance was then ordered to be opened, which was done by the Secretaries, and the name of the author, Prof. LEWIS M. HAUPT, of the University of Pennsylvania, was announced as the person entitled to the said premium. On motion, the President was authorized to appoint at his leisure a committee of three members to attend to all the details connected with the preparation of the medal, etc. [The President subsequently appointed Messrs. J. Sergeant Price, R. M. Bache and Henry Phillips, Jr., as such committee.]

The Secretaries presented a communication by Rev. Charles W. King, entitled "The Epitaph of M. Verrius Flaccus."

Prof. Houston exhibited a Palladium Hair Spring of a non-magnetizable watch and mentioned the experiments he had already made and was making on it.

The Finance Committee presented its Annual Report, and the appropriations for the ensuing year were passed.

The Committee on Volapük reported progress, and the report was made the special order for the next meeting.

This being the regular meeting for balloting for candidates, a ballot was gone into, and Mr. Samuel Castner, Jr., of Philadelphia, was declared duly elected a member of the Society.

And the Society was adjourned by the President.

INDEX TO VOL. XXIV.

Stated Meetings Held.

	Page.		Page.
1886, December 17	184	1887, May 20	206
1887, January 7	187	September 2	403
January 21	190	September 16	410
February 4	192	October 7	412
February 18	195	October 21	414
March 4	196	November 4	416
March 18	198	November 18	417
April 1	199	December 2	434
April 15	201	December 16	444
May 6	203		

New Members Elected.

December 17, 1886.

Morton W. Easton	185
William F. Norris	185
James McAlister	186
Charles S. Dolley	186
John A. Ryder	186
Hermann V. Hilprecht	186
George W. Childs	186
W. B. Scott	186
Henry Sumner Maine	186
Monier Monier-Williams	186
Hugo Von Meltzel	186
Paul Hunfalvy	186
G. Weil	186
Henri Kiepert	186
Adolph Bastian	186
Friederich Mueller	186
Matthæus Much	186
Albert Reville	186
Paul Topinard	186
Remi Simeon	186
Conrad Leemans	186
George Curtius	186
Julius Platzmann	186
Lucien Adam	186
Guido Cora	186
Crescencio Carrillo	186
Juan de Dias de la Rada y Delgada	186
Hyacinthe de Charency	186
G. A. Hirn	186

February 18, 1887.

John S. Billings	196
Henry F. Osborn	196

May 20, 1887.

Joseph S. Harris	208
William Powell Wilson	208
James Tyson	208
William Henry Rawle	208
Henry D. Wireman	208
Albert H. Smyth	208
H. C. de S. Abbott	208
Henry H. Houston	208
William T. Barnard	208

October 21, 1887.

Guisèppe Menenghini	415
Edgar F. Smith	415

December 16, 1887.

Samuel Castner, Jr., 446.

Decease of Members.

Isaac Lea	185
Pliny Earle Chase	188
Bernard Studer	207
John T. Napier	207
S. F. Baird	408
Charles Rau	408
Alvan Clark	408
Wm. Bacon Stevens	408
N. A. Randolph	408
Gustav Kirchhoff	417
Thomas M. Walter	417
Alfred Mordecai	417
Middleton Goldsmith	446

Papers Presented. *Page.*

BARKER, GEORGE F.
On the Henry Draper Memorial Photographs of Stellar Spectra 166

BLASIUS, WILLIAM.
The Signal Service Bureau, its Methods and Results 179

BRINTON, DANIEL G.
Critical Remarks on the Editions of Diego de Landa's Writings 1
Were the Toltecs an Historical Nationality 229
On the so-called Alaguilac Language of Guatemala 366
On an Ancient Human Footprint from Nicaragua 437

CLAYPOLE, E. W.
Organic Variation Indefinite not Definite in Direction—an Outcome of Environment 113

COPE, E. D.
Synopsis of the Batrachia and Reptilia obtained by H. H. Smith in the Province of Mato Grosso, Brazil 44
Contribution to the History of the Vertebrata of the Trias of North America . . 209
Classification and Philogeny of the Artiodactyla 377

FRAZER, PERSIFOR.
Remarks on Dr. Barker's paper on Stellar Spectra 171

GARMAN, SAMUEL.
On the Reptiles and Batrachians of Grand Cayman 273
On West India Reptiles in the Museum of Comparative Zoölogy at Cambridge, Mass. 278

GARRETT, PHILIP C.
Memoir of Pliny Earle Chase 287

GENTH, F. A.
Contributions from the Chemical Laboratory of the University of Pennsylvania. No. XXIX. Contributions to Mineralogy 23

HOUSTON, EDWIN A.
On a Non-magnetizable Watch 418
On the Gramophone 420

KIRKWOOD, DANIEL.
The Relations of Aerolites to Shooting Stars 111
Biela's Comet and the Large Meteors of November 27-30 242
Note on the Possible Existence of Fireballs and Meteorites in the Stream of Bielids 436

LEIDY, JOSEPH.
Biographical Notice of Isaac Lea, LL D 400

MOONEY, JAMES.
The Medical Mythology of Ireland 136

OSBORN, HENRY F.
The Triassic Mammals, Dromatherium and Microconodon 109

PACKARD, A. S.
On the Systematic Position of the Mallophaga 264

SCOTT, W. B., and OSBORN, HENRY F.
Preliminary Report on the Vertebrate Fossils of the Uinta Formation collected by the Princeton Expedition of 1886 255

SMITH, EDGAR F. Page.
Electrolysis of Lead Solutions. Determination of Boric Acid. Dihalogen Derivatives of Salicylic Acid. Barite 428

STEVENSON, JOHN J.
A Geological Reconnaissance of Bland, Giles, Wythe, and portions of Pulaski and Montgomery Counties, of Virginia 61

STOKES, ALFRED C.
Notices of New Fresh-water Infusoria 244

STOWELL, T. B.
The Facial Nerve in the Domestic Cat 8

TAYLOR, ALFRED B.
Octonary Numeration and its Application to a System of Weights and Measures. 296

VAUX, RICHARD.
Obituary Notice of James R. Ludlow 19

Miscellaneous Business.

Committees, Standing, appointed 191, 194
Reports of 185, 189, 191, 192, 411, 413
Special 201, 203, 205, 208, 415, 417, 421, 436
Council Minutes submitted 196, 197, 418
Recommendations of 196, 197, 418
Exchanges ordered 185, 406, 414, 418
Humboldt portrait, presentation of 406, 411, 417
Librarian nominated 189
Elected 191
Members take their seats 187, 190, 195, 196, 206, 412, 414, 417, 434
Nominations of, read 185, 186, 195, 208, 409, 411, 413, 417, 419
Elected 185, 186, 196, 208, 415
Michaux Legacy received 194, 205, 409, 415
Expended 192, 421
To be re-invested 197, 205, 208
Lectures 435
Magellanic Premium, communication for, signed "Baboika." 197, 199, 207
Signed "Magellan" 207, 418
Award recommended by Council to "Magellan" 419
Officers elected 188
Photographs received from members 185, 187, 200, 413, 416, 418
Report of Treasurer 447
Trustees Building Fund 203
Finance Committee 446
Seybert Legacy to be receipted for 417
Society subscribes to E. Muybridge's work 191
Loans portraits to Academy of Fine Arts 411
College Physicians 184, 193
Invites Society of Naturalists to visit its Hall 185
Invites American Association for the Study of Modern Languages to visit its Hall. 445
Volapük, Committee on, appointed 415
Reports 421, 436

Erratum.

On page 204, "Pseudo-maple Mimetites" should read "Pseudo-morphic Mimetites."

him the communication, description, or model, except the officer to whom it shall be entrusted; nor shall such officer part with the same out of his custody, without a special order of the Society for that purpose.

6. The Society, having previously referred the several communications from candidates for the premium, then depending, to the consideration of the twelve counsellors and other officers of the Society, and having received their report thereon, shall, at one of their stated meetings in the month of December, annually, after the expiration of this current year (of the time and place, together with the particular occasion of which meeting due notice shall be previously given, by public advertisement) proceed to final adjudication of the said premium; and, after due consideration had, a vote shall first be taken on this question, viz.: Whether any of the communications then under inspection be worthy of the proposed premium? If this question be determined in the negative, the whole business shall be deferred till another year; but if in the affirmative, the Society shall proceed to determine by ballot, given by the members at large, the discovery, invention or improvement most useful and worthy; and that discovery, invention, or improvement which shall be found to have a majority of concurring votes in its favor shall be successful; and then, and not till then, the sealed letter accompanying the crowned performance shall be opened, and the name of the author announced as the person entitled to the said premium.

7. No member of the Society who is a candidate for the premium then depending, or who hath not previously declared to the Society, that he has considered and weighed, according to the best of his judgment, the comparative merits of the several claims then under consideration, shall sit in judgment, or give his vote in awarding the said premium.

8. A full account of the crowned subject shall be published by the Society, as soon as may be after the adjudication, either in a separate publication, or in the next succeeding volume of their Transactions, or in both.

9. The unsuccessful performances shall remain under consideration, and their authors be considered as candidates for the premium for five years next succeeding the time of their presentment; except such performances as their authors may, in the meantime, think fit to withdraw. And the Society shall annually publish an abstract of the titles, object, or subject matter of the communications, so under consideration; such only excepted as the Society shall think not worthy of public notice.

10. The letters containing the names of authors whose performances shall be rejected, or which shall be found unsuccessful after a trial of five years, shall be burnt before the Society, without breaking the seals.

11. In case there should be a failure, in any year, of any communication worthy of the proposed premium, there will then be two premiums to be awarded the next year. But no accumulation of premiums

shall entitle the author to more than one premium for any one discovery, invention or improvement.

12. The premium shall consist of an oval plate of solid standard gold of the value of ten guineas. On one side thereof shall be neatly engraved a short Latin motto suited to the occasion, together with the words: "The Premium of John Hyacinth de Magellan, of London, established in the year 1786;" and on the other side of the plate shall be engraved these words: "Awarded by the A. P. S. for the discovery of——A.D.——." And the seal of the Society shall be annexed to the medal by a ribbon passing through a small hole at the lower edge thereof.

SECTION 2. The Magellanic fund of two hundred guineas shall be considered as ten hundred and fifty dollars, and shall be invested separately from the other funds belonging to or under the care of the Society, and a separate and distinct account of it shall be kept by the treasurer.

The said fund shall be credited with the sum of one hundred dollars, to represent the two premiums for which the Society is now liable.

The treasurer shall credit the said fund with the interest received on the investment thereof, and, if any surplus of said interest shall remain after providing for the premiums which may then be demandable, said surplus shall be used by the Society for making publication of the terms of the said premium, and for such purposes as may be authorized by its charter and laws.

The treasurer shall, at the first stated meeting of the Society in the month of December annually, make a report of the state of said fund and of the investment thereof.

☞ Members who have not as yet sent their photographs for the Society's album will confer a favor by so doing.

☞ Please communicate any change of address or inaccuracy in name.

☞ A few sets of the Society's Transactions, New Series, 1818 to 1882, XVI vols., 4to, can be obtained from the Librarian. Price, $60.00.